Popular Astronomy.

Vol. XII No. 3. MARCH, 1904. Whole No. 113.

MEASURING THE DISTANCE OF THE SUN BY MEANS OF THE PLANET EROS.

H. C. WILSON.

The writer having recently finished the reduction of measures of 67 photographs of the planet Eros, which were taken during the Fall and Winter of 1900-01 for the purpose of determining the solar parallax, was interested in comparing the results with the similar photographic results published by the Observatories of Paris and Bordeaux, and in getting out from the three sets of measures a preliminary value of the parallax. The three sets agree so well and exhibit so well the accuracy of the photographic method that Professor Payne has asked me to prepare an article describing as plainly as possible the process of attacking the problem.

We wish here to acknowledge our indebtedness to Professor Leavenworth and the authorities of the University of Minnesota for the loan during the summer of 1902 of the fine Repsold Measuring machine belonging to the University Observatory, to the Trustees of the B. A. Gould Astronomical Fund for two grants of money, amounting in all to $550, and to Dr. DeLisle Stewart now of the Cincinnati Observatory, and Professor Anne S. Young of Mt. Holyoke Observatory, for their valuable assistance in the work of measuring and reducing the photographs.

A short historical note is necessary first to the clear understanding of the problem.

On the 13th of August 1898, Mr. Witt of the Urania Observatory in Berlin, discovered on one of his stellar photographs a small planet to which he afterwards gave the name of Eros. It had been photographed by Mr. Charlois, at the Observatory of Nice, a few hours earlier on the same night but was not discovered by him until later. Now the discovery of a small planet ordinarily attracts little attention, for a dozen or more of them are discovered every year, but this one excited interest at once because of its extraordinarily rapid apparent motion. When its orbit was calculated it was found to be moving in an orbit which at times approaches nearer to the path of the Earth than does

the track of any of the other known planet, great or small, its average distance from the Sun being less than that of Mars. At its nearest possible approach it may come within 13,000,000 miles of the Earth. It is a tiny planet, probably not more than 20 miles in diameter, appearing in the most powerful telescope as a very small bright point of light with no measurable disc. On account of these two things, the nearness of the planet's approach to the Earth and the smallness of its image as seen in the telescope or impressed upon the photographic plate, thus permitting its position in space to be measured with extreme accuracy, Eros becomes an important body in the solar system. It was at once pointed out that Eros afforded a far better means of obtaining the parallax of the Sun, and so the distance of the Earth from the Sun, than any that had been hitherto employed. Some of the asteroids had already been used in determining the Sun's parallax and had yielded very satisfactory results, but those used did not approach anywhere near so close to the Earth as does Eros, so that from the latter much more accurate results may be expected.

Unfortunately Eros and the Earth do not often pass the points of nearest approach of their orbits at the same time. The relation of the two orbits is shown in the diagram Fig. 1. Eros makes a complete circuit around the Sun in 1.76 years, while the Earth revolves in one year. If the two planets were to start together near the point P, while Eros would make the circuit of its orbit once, the Earth would go around its path once and three-quarters of the way again, and in 2.31 years the latter would overtake the former, almost a third of the way around its second circuit. After 2.31 years more the two planets would again be in conjunction, etc. After seven years the two would be near the point P together, but not in line with the Sun so as to give the shortest distance. The actual conjunction of the planets (opposition of Eros) would occur about 30° around to the right from P. A quite close conjunction occurs after 30 years and a still closer one after 37 years have elapsed. If the elements of the orbit of Eros have not been changed too much by the attraction of the other planets, there was a very close conjunction in 1880. Another will occur therefore in 1917 and a less favorable one in 1910.

At the international conference of astronomers at Paris in 1900, it was decided not to wait for the most favorable oppositions of Eros in 1910, 1917 and 1924, but, since at the opposition in 1900 the planet would come nearer to the Earth than had any

other planet, to enter at once upon a coöperative campaign for determining the parallax of Eros, using both the micrometric and photographic methods. Circulars were sent out from Paris to all the Observatories, asking them to take part in the work. Forty-seven Observatories responded, agreeing to take some part in the work. Of these ten were in the United States, one in Mexico, and two in South America; thirty-two were in Europe and two in Africa. The path of the planet was calculated for the

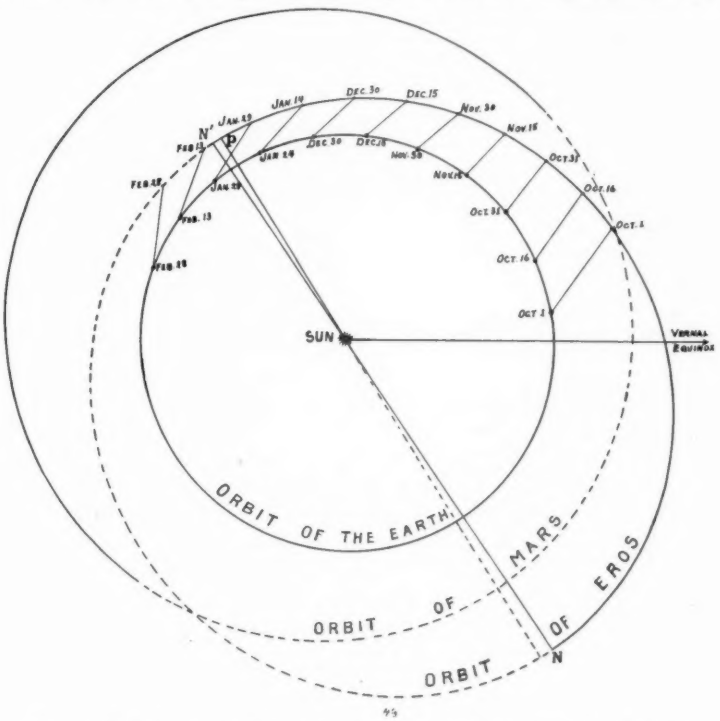


FIG. 1. THE RELATIVE POSITIONS OF EROS AND EARTH FROM OCT. 1, 1900 TO FEB. 28, 1901.

period when it was to be near the Earth and a list of over 700 stars lying near its path was selected for reference stars for the measurement of the photographs. The places of these stars were determined very accurately with the meridian circles at thirteen observatories, during the period in which the planet was being observed. The observatories joining in this part of the work, whose results have been published, were those of Abbadia, Green-

wich, Koenigsberg, Lisbon, Lick, Marseilles, Nice, Paris, Rome, Toulouse, San Fernando, Strassburg and Washington.

The following list of observatories took part in the micrometric measures or photographs of the planet, M signifying micrometer and P photographs, the figures following the letters denoting the number of nights on which the planet was observed:

Algiers, P 84
Arcetri, Florence, M 29
Bamberg, Heliometer 48
Besancon, M 32
Bordeaux, M 12, P 34
Cambridge, Eng., P 39
Catania, P
Cape of Good Hope, P
Charlottesville, McCormick, M 27
Christiana, M 50
Cordoba, M 17, P 3
Denver, M
Dublin, P 17
Dusseldorf, M, 11
Edinburgh, M 22
Flagstaff, M 19
Greenwich, P 98
Helsingfors, P 48
Kasan, M 15
Kœnigsberg, M 88
Königstuhl, Heidelberg, P 6
Lyons, M 36
Madison, Washburn, M 60
Marseilles, M 74
Minneapolis, University, P 59
Mt. Hamilton, Lick M 29, P 68
Nice, M 69; several instruments
Northfield, P 56, M 21
Oxford, P 52
Padua, M 41
Paris, M 58, P 68
Poulkova, M 50, P 27
San Fernando, P 51
Strassburg, M 33
Tachkent, P 23
Tacubaya, M 61 P
Teramo, M 100
Toulouse, M 47, P 36
Uccle, Belgium, M 2
Upsala, P 30
Washington, M 61
Williams Bay, Yerkes, M 67

As may be inferred from the above table, a great mass of material was at once accumulated for the solution of the problem, but it all had to be reduced and published before it could be made available for its purpose, and a very great amount of work has been done upon it during the past three years. There is very much yet to be done, especially in the measurement and reduction of the photographic plates, which is very tedious business, so that it will be a long time yet before the final parallax can be determined. All the more interest will therefore attach to the preliminary values, which may indicate somewhere near what the final result may be.

The Plan of the Observations.

In speaking of the details of the work I shall have to refer chiefly to the plan carried out at Northfield, since no specific instructions were given out and each observer had to devise his own methods of carrying out the general plan. If the reader will refer to the diagram Fig. 1, he will see that Eros was roughly opposite the Sun, as seen from the Earth, from October 1900 to February 1901, so that it might be observed during the greater part of the night. In order to imagine how the planet moved through the sky one must think of the orbit of Eros as inclined to the plane of the paper, being rotated on the line of Nodes NN′

through an angle of ten degrees, the smooth part of the curve standing in front of the paper and the dotted portions behind it. The line Oct. 1—Oct. 1 thus stands up at an angle of about 45°, instead of lying flat on the paper. Now imagine the eye to move along the Earth's path, looking out at the planet as it moves across the sky, and the reader can possibly see that it will describe a great loop in the heavens. In Fig. 2 a portion of the apparent path of Eros among the stars is shown, extending from Sept, 20, 1900 to Jan. 6, 1901. This chart was prepared by the writer in 1900, in order to easily identify Eros at the time when a photograph or a micrometer measure was to be taken. The chart shows only the stars down to the magnitude 9.5, while Eros much of the time was considerably fainter and there were thousands of other faint stars along its path, but it was possible by the aid of the chart to locate its place closely enough for a photograph, or so that a few minutes micrometer measures would decide which of the faint objects near its place was really the planet.

The general plan of work was that each of those observers who were provided with photographic telescopes should take photographs of the region about the planet all along its path from October to February, each photograph covering a field of approximately 2° diameter, and that, those working with micrometers should measure the distance between the planet and the nearest stars to it on each night, trusting to the photographs to give them the exact positions of these stars.

Two plans were adopted for arranging the times of the observations. One was to make them simultaneous at stations far apart on the Earth, at a favorable moment for both stations; the other was to make them at widely different hours at the same station, that is in the morning and evening. The theories of the two plans are shown in the diagrams Fig. 3 and Fig. 4. In Fig. 3, since the difference in longitude between Paris and Northfield is a little over six hours, the best time to make simultaneous observations would be when Eros was over the meridian midway between the two cities, that is, about three hours before Eros passed the meridian at Northfield and three hours after it had passed that of Paris. Eros would then be near the star *b* as seen from Northfield, but near the star *c* as seen from Paris, while its true direction from the center of the Earth would be toward the star *a*. This displacement is called the parallax of Eros and it depends clearly upon the distance of the planet from the Earth and the distance between the observing stations. The

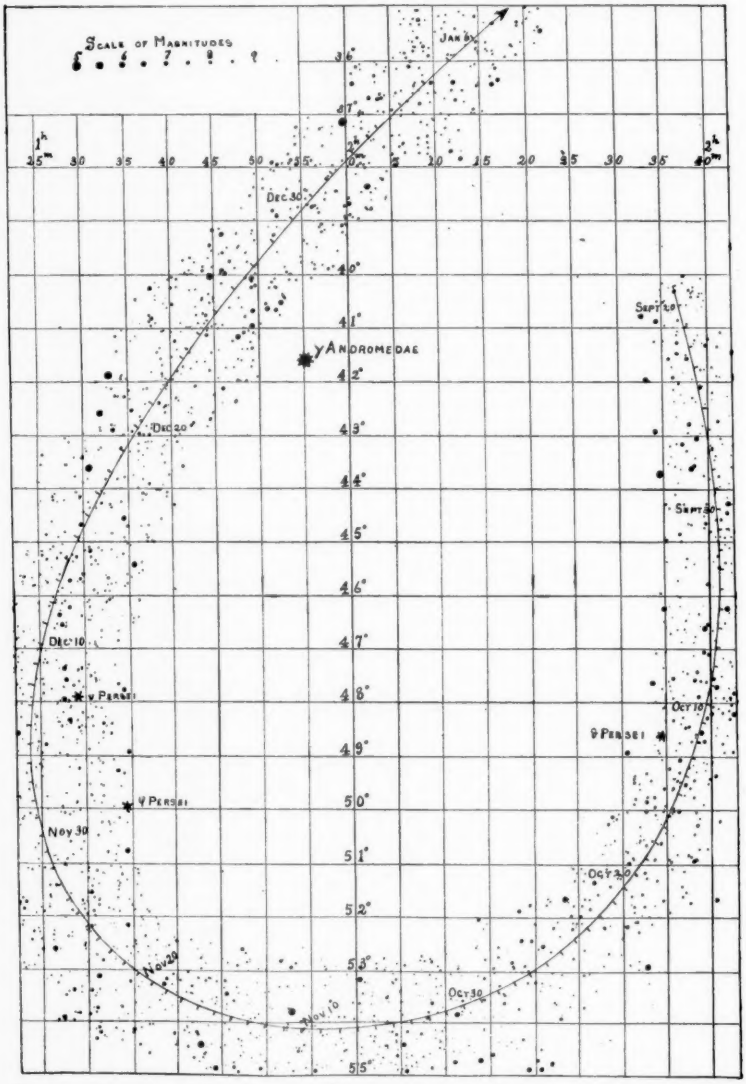


FIG. 2. THE APPARENT PATH OF EROS AMONG THE STARS FROM SEPT. 20, 1900 TO JAN. 6, 1901.

greater the latter and the less the former, the greater the parallax. Theoretically this first plan avoids the errors which might enter into the calculation of the position of Eros from the elements of its motion which are not exactly known. Practically, however, very few of the observations in Europe and America are found to have been simultaneous, so that equally good if not better results are to be expected from the second plan.

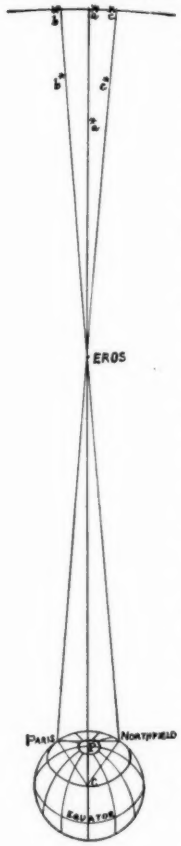


FIG. 3.

As seen from the same Observatory when the planet is from 4 to 6 hours east of the meridian and when it is as far to the west (evening and morning, Fig. 4) the displacement with reference to neighboring stars is greater than in the former case, for the observing stations are farther apart. An extremely accurate ephemeris of Eros has been calculated by Professor Millosevich, Director of the observatory at Rome. He has used eight-place logarithm tables so that the right ascensions are computed to the thousandth of a second of time and the declinations to the hundreths of a second of arc. I have been surprised at the extreme accuracy of this ephemeris and believe that the effects of its errors may be easily eliminated from the parallax.

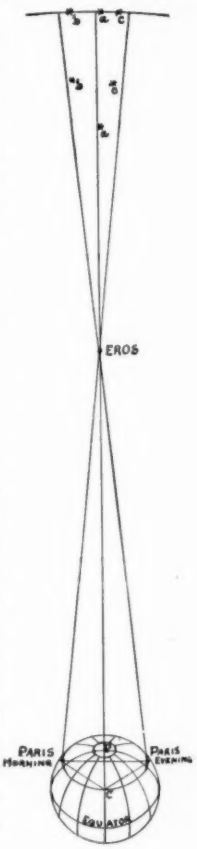


FIG. 4.

In both Figs. 3 and 4, of course, the parallax is greatly exaggerated. If the figures were drawn to scale, with the Earth ⅝ of an inch in diameter Eros at its nearest would have to be represented as 80 feet distant and the stars would be two or more million times as far. Their distance is such that their displacement as seen from the two stations on the Earth is wholly negligible. The angle at Eros between the two lines extending to points

upon opposite sides of the Earth is at most a little over two minutes of arc.

The Photographs.

At Northfield the photographs were taken with the 8½-inch Clark refractor of 107 inches focal length. This telescope has three objective lenses, which give sharp small star images over the greater part of a field two degrees in diameter. It is provided with a 5-inch guiding telescope, of the same focal length, fastened rigidly to it at the objective and eye ends and in the middle. The plates used were ordinary commercial plates, of the Cramer Crown brand, 4x5 inches in size. No reseaux was impressed upon the plates as was done in the European Observatories. For making separate exposures on the same plate a reticle of spider threads illuminated by an electric lamp was placed in the eyepiece of the guiding telescope, forming a small rectangle which was adjusted to the center of the field of the photograph. Five exposures were usually made, one of five minutes duration with the guiding star at the north corner of the rectangle, one of one minute at the east corner, the third of two minutes at the south corner, the fourth of one minute at the west corner and the fifth of five minutes duration again at the north corner, the images of each star at this corner being superposed. In the mean time the planet would have moved so that its two five-minute images would be entirely separate, making the north image double. It was thus very easy to identify the planet among the neighboring stars. In Fig. 5 (Plate VII) is given a print from the central portion of one of the places. It has been enlarged to three times the scale of the original plate in order to make the images large enough to reproduce by half-tone engraving, but still many of the images are too small to show. The guiding star was the right lower one of the three brightest ones near the center. The planet is a centimeter to the left and a little below the guiding star. Above and to the right of it, the middle one of the three bright stars is an unequal double. Fig. 6 gives the central portion of a plate in which Eros itself was used as the guide. Its two north images in this case are superposed, while because of its motion every star has a double image at the north corner of the square.

Measuring the Photographs.

During the summer of 1902 Dr. DeLisle Stewart and the writer, with minor assistants as recorders, were able to measure all of our Eros plates, with the exception of a few which were rejected

because of imperfect star images. Each plate was placed in the Repsold measuring machine in four positions, differing by angles of 90°. A complete set of measures of differences in right ascension, or rather in the *x*-co-ordinate corresponding to right ascension, between the planet and eight or ten reference stars, was taken with the position circle of the machine set at the reading corresponding to 0°. The plate was then revolved exactly 180° and a second set of measures of the *x*-co-ordinates made. It was turned then through just 90° and a set of measures of the co-ordinates, corresponding to difference of declination, taken. Once more the plate was revolved through 180° and a second set of measures of the *y* co-ordinates was taken. Each single measure consisted in two pointings of the micrometer wires of the machine upon each of the four or five images of the planet or of a star and four pointings upon the one of two nearest scale divisions. All the precautions we could think of were taken to eliminate systematic errors in the measures, such as forward and backward movement of the screw, pointing on the scale both before and after the pointings on a star, etc. Duplicate pointings were made on the central or guide star and on Eros at the beginning and end of each of the four sets of measures of each plate. These duplicate measures usually agreed within 0″.10. The following is a portion of one of the original records:

MEASURES OF PLATE 10, JULY 2, 1902.

Position Circle 0° 45′ 2″				180° 44′ 59″		180° 45′ 6″		0° 44′ 59″	
Star.	Scale Estimates.			Micrometer. rev.	rev.	Scale Estimates.		Micrometer. rev.	rev.
46°.641	64ᵈ.3	264ᵈ.1	Scale	9.516	9.517	64ᵈ.2	266ᵈ.7	Scale 9.294	9.294
			N	10.981	10.984			N 11.098	11.101
Temp. 73°.3			E	10.243	10.242	Temp. 73°.9		E 11.834	11.838
			S	11.174	11.165			S 10.906	10.901
			W	11.864	11.872			W 10.212	10.206
			N	10.985	10.984			N 11.103	11.100
			Scale	11.517	11.516			Scale 11.296	11.296
Eros	57.5	260.1	Scale	10.002	10.002	70.9	270.7	Scale 10.813	10.813
			N	10.963	10.971			N 11.118	11.123
			E	10.138	10.144			E 11.933	11.944
			S	11.152	11.156			S 10.920	10.934
			W	11.902	11.894			W 10.184	10.191
			N	10.920	10.924			N 11.161	11.164
			Scale	12.002	12.005			Scale 12.817	12.817
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

The entire record of the original measures of this plate covers nineteen times the above space, and the time occupied was about seven hours.

As 10 revolutions of the micrometer screw of the measuring

machine equal one millimeter, an inspection of these measures shows that the error of pointing upon the scale divisions was only 1 or 2 ten thousandths of a millimeter or about one-hundredth of a second of arc, the scale of our plates being 1 millimeter = 75.9″. The pointings upon the star images were subject to about ten times as great errors on the average, that is about ± 0″.10. On the plates on which the definition was poor, and where the star images were large the errors were found to be considerably larger, amounting to ± 0″.30. Very few single pointings show discrepancies as large as 1″.

Reduction of Measures.

The reductions occupied much more time than the measures themselves. First the separate pointings on each image were averaged, then corrections were applied for the errors of the scale divisions and the error of runs of the micrometer. Then the micrometer readings were converted into scale reading in millimeters and the differences were taken which gave the rectangular co-ordinates x and y of each image from the corresponding image of the guide star at the center of the plate. Then the means were taken of the measures made in the two opposite positions of the plate for each co-ordinate, and finally the averages of the co-ordinates as obtained from the five different images were taken. It was found after a number of preliminary reductions that the results obtained from the averages of the five images was the same as if the co-ordinates of the five images were reduced separately and afterwards averaged. Next the averaged co-ordinates were converted into seconds of arc by multiplying x by 75.9″ sec δ_0, and y by 75.9″, δ_0 being the declination of the center of the plate and 75.9″ the approximate value of one division of the scale or 1mm. This was done both by the use of Crelles multiplication table and by the use of six-place logarithms, for a complete check upon that step. The previous steps were checked quite satisfactorily by the comparison of the results from the different images.

The next step was to calculate the same rectangular co-ordinates, x sec δ_0 and y, from the positions of the stars as given by the meridian circle observations of the thirteen Observatories, as published in circulars 8 and 9 of the International Conference. This was also done in duplicate by two computers by two entirely different methods. One computer used the following modification of Turner's formulæ, which adapts them to the use of seven-place logarithms for small angles:

$$\cot Q = \cot \delta \cos (\alpha - \alpha_0)$$

$$Y = \tan (Q - \delta_0) = Q - \delta_0 + \frac{1}{3}(Q - \delta_0)^3 \sin^2 1'' + \frac{2}{15}(Q - \delta_0)^5 \sin^4 1'' + \text{etc.}$$

$$= Q - \delta_0 + t$$

$$X \sec \delta_0 = (\alpha - \alpha_0 + t) \cos Q \sec \delta_0 \sec (Q - \delta_0)$$

in which α and δ are the right ascension and declination of a star for 1900.0, α_0 and δ_0 are the similar co-ordinatesof the center of the plate (the guiding star in this case), and t is the reduction of the arc to the tangent for the angle to which it is added and is taken from a small table which is easily prepared.

The second computer used five-place logarithms, employing Jacoby's formulæ

$$X \sec \delta_0 - \Delta\alpha = -\Delta\alpha \cdot \Delta\delta \tan \delta_0 \sin 1'' + \Delta\alpha^3 \frac{1}{3}(1 - \frac{3}{2}\sin^2\delta_0) \sin^2 1''$$

$$Y - \Delta\delta = \Delta\alpha^2 \cdot \frac{1}{4} \sin 2\delta_0 \sin 1'' + \Delta\alpha^2\Delta\delta \cdot \frac{1}{2} \cos 2\delta_0 \sin^2 1'' + \Delta\delta^3 \cdot \frac{1}{3} \sin^2 1''$$

The two were required to agree within 0.02″ in their values of X sec δ_0 and Y and, in case of this amount of discrepancy, preference was given to Jacoby's formula, for the reason that the limit of accuracy of seven-place logarithms in Turner's formulæ is 0.02″, while Jacoby's formulæ permit the thousandth of a second of arc to be computed.

For about half of the plates corrections were applied to the co-ordinates x sec δ_0 and y for the second order terms of differential refraction by the use of Turner's formulæ

$$\Delta_2 x \sec \delta_0 = -\mu \sec \delta^0 [H (2 + H^2) x^2 + G (1 + 2H^2) xy + H (1 + G^2) y^2]$$

$$\Delta_2 y = -\mu [G (1 + H^2) x^2 + H (1 + 2G^2) xy + G (2 + G^2) y^2]$$

in which μ is the constant of refraction, $G = \tan \zeta_0 \cos q$ and $H = \tan \zeta_0 \sin q$, ζ_0 and q being the zenith distance and parallactic angle at the center of the plate. Three small tables were prepared which gave the co-efficients of x^2, xy and y^2 in these formulæ with the arguments G and H, greatly simplifying the computations. When the zenith distance was less than 30° these corrections were found to be less than 0.01″ and were therefore neglected.

The first order terms of differential refraction, together with those of precession, nutation and aberration, being linear in form, were considered as producing errors of the scale value and

TABLE I.

POSITIONS OF EROS, COMPARED WITH THE EPHEMERIS IN CIRCULAR No. 9.

Plate No.	Central Standard Time. 1900.				Apparent R. A.			Apparent Decl.			Parallax. R. A.	Parallax. Decl.	O − C Δα	O − C Δδ	No. of Images.
		h	m	s	h	m	s	°	′	″	s	″	s	″	
4	Sept. 26	10	17	10.7	2	42	51.200	+43	9	2.12	− 0.856	+ 4.29	+ 0.038	+ 1.46	2
5	26	12	40	10.7	2	42	52.894	43	11	21.34	0.451	1.12	− 0.005	1.88	2
7	Oct. 5	10	49	27.0	2	43	56.773	46	30	53.65	0.827	2.08	0.071	1.64	2
8	9	8	59	22.0	2	42	54.815	47	54	47.44	1.141	4.97	0.112	2.05	5
9	10	8	48	0.0	2	42	29.314	48	15	26.17	1.173	5.24	0.103	1.69	5
10	10	12	5	2.5	2	42	24.777	48	18	21.38	0.474	− 0.50	0.097	1.44	5
11	11	7	59	6.0	2	42	0.539	48	35	15.56	1.245	+ 6.99	0.117	1.75	5
12	11	12	6	7.0	2	41	54.243	48	38	53.03	0.465	− 0.66	0.099	1.80	5
13	12	8	32	20.0	2	41	25.630	48	56	0.22	1.228	+ 5.48	0.107	1.90	5
14	12	12	23	38.0	2	41	18.907	48	59	19.85	0.367	− 1.07	0.086	1.66	7
15	16	7	36	30.7	2	38	26.888	50	12	40.85	1.362	+ 7.13	0.144	1.43	5
16	16	11	19	12.7	2	38	17.775	50	15	41.03	0.638	− 0.76	0.113	1.72	9
16	16	11	53	32.7	2	38	16.253	50	16	7.87	0.449	− 1.37	0.139	1.50	2
17	18	8	21	39.8	2	36	27.542	50	49	29.60	1.333	+ 4.67	0.154	1.62	7
18	18	11	30	56.8	2	36	18.379	50	51	54.32	0.542	− 1.38	0.158	1.68	15
19	19	8	3	41.4	2	35	22.781	51	6	37.39	1.382	+ 5.23	0.175	1.75	5
20	19	12	32	44.4	2	35	8.763	51	9	55.97	0.139	− 2.24	0.174	1.70	7
20a	23	7	51	44.5	2	30	16.219	52	10	15.84	1.459	+ 4.80	0.210	1.65	5
20b	23	12	40	46.5	2	29	57.452	52	13	19.46	+ 0.040	− 2.75	0.222	1.47	3
21	24	8	36	24.2	2	28	45.660	52	25	5.60	− 1.335	+ 2.54	0.217	1.23	5
22	24	12	3	57.2	2	28	31.480	52	27	11.85	0.168	− 2.80	0.226	1.45	7
23	25	7	48	41.2	2	27	17.041	52	38	16.25	1.487	+ 4.41	0.209	1.46	5
24	26	7	34	44.5	2	25	42.296	52	51	5.28	1.530	4.81	0.229	1.72	5
25	Nov. 1	7	38	50.6	2	14	56.198	53	51	55.41	1.506	3.20	0.275	1.15	5
26	2	7	9	54.0	2	13	1.460	53	58	50.72	1.639	+ 4.05	0.319	0.97	5
27	7	9	19	20.3	2	2	41.037	54	20	11.39	0.853	− 2.54	0.347	0.33	6
28	8	8	56	51.4	2	0	39.306	54	21	19.43	0.983	− 2.10	0.351	0.89	1
29	10	5	56	20.3	1	56	49.081	24	20	35.49	1.845	+ 5.69	0.255	0.52	1
30	13	6	8	22 6	1	50	46 350	54	12	2.19	− 1.793	+ 4.16	0.283	+ 0.15	5
31	13	11	34	26.0	1	50	17.386	54	11	8.15	+ 0.525	− 3.64	0.314	− 0.14	5
32	13	16	45	33.5	1	49	50.685	54	9	52 16	1.962	+ 10.72	0.294	− 0.09	5
33	14	17	29	32.0	1	47	51.735	54	4	15.47	1.888	13.91	0,355	+ 0.32	4
34	14	17	48	18.0	1	47	50.327	54	4	9.80	+ 1.845	15.00	− 0.321	0.38	2

35		15	5	47	33.3	1	46	57.428	54	1	14.23	− 1.842	+ 4.79	− 0.335	+ 0.32	5
36		22	6	45	27.0	1	35	23.451	52	51	40.63	− 1.402	0.29	0.349	− 0.42	5
37		22	17	21	30.2	1	34	44.722	52	45	30.90	+ 1.819	17.06	0.345	0.02	5
38		24	6	17	34 8	1	32	53.067	52	23	58.55	− 1.509	+ 1.28	0.345	0.58	5
39		26	7	48	35.8	1	30	40.611	51	51	52.39	− 0.791	− 2.26	0.319	0.56	5
41		26	17	23	15.0	1	30	15.689	51	44	56.11	+ 1.724	+ 18.83	0.348	0.50	5
42		29	6	22	43.0	1	28	20.468	51	0	43.03	− 1.317	0.53	0.308	0.61	4
43		29	16	58	42.7	1	28	1.261	50	52	15.17	+ 1.760	18.62	0.246	0.47	5
44		30	6	8	43.4	1	27	46.067	50	42	14.14	− 1.375	+ 1.06	0.280	0.62	4
45	Dec.	4	7	27	58.5	1	26	33.061	49	20	55.79	0.665	− 1.55	0.363	0.94	4
47		8	5	57	22.1	1	27	9.074	47	54	33.09	1.203	+ 1.39	0.271	0.90	4
48		11	5	45	48.4	1	28	43.792	46	45	6.74	1.194	1.94	0.286	0.79	4
49		12	6	0	41.0	1	29	28.569	46	21	4.03	1.067	1.45	0.275	0.46	5
50		18	5	54	29.5	1	36	3.295	43	53	29.01	− 0.959	2.20	0.260	0.83	5
51		18	15	28	59.6	1	36	34.393	43	42	9.55	+ 1.698	19 27	0.289	0.46	2
52		19	5	43	59.6	1	37	29.046	43	28	26.83	− 1.007	2.65	0.282	0.52	5
53		19	14	47	6.4	1	38	0.238	43	18	39.69	+ 1.781	17.10	0.322	0.64	3
54		20	7	35	7.5	1	39	7.458	43	1	10.80	− 0.158	0.62	0.264	0.70	5
55		21	6	16	59.6	1	40	40.457	42	37	5.00	− 0.734	1.96	0.220	1.08	2
56		25	9	54	34.0	1	48	19.758	40	50	37.64	+ 0.871	3.37	0.281	1.11	4
57		28	10	0	4.8	1	54	45.866	39	33	9.00	+ 0.999	4.63	0.244	1.08	5
59		31	6	9	5.8	2	1	29.336	38	19	51.57	− 0.616	3.72	0.189	1.11	5
	1901.															
60	Jan.	1	5	49	12.2	2	3	56.700	37	53	23.50	0.736	4.31	0.238	1.24	5
61		2	6	3	10	2	6	31.314	37	28	20.23	0.628	4.18	− 0.224	− 1.31	4
62		14	6	3	58.8	2	41	27.586	32	20	6.13	0.495	6.18	+ 0.036	+ 0.84	3
63		15	5	58	39.2	2	44	39.727	31	54	42.07	0.521	6.43	0.000	0.09	1
65		18	6	6	13.0	2	54	33.000	30	38	25.56	0.451	6.81	+ 0.025	1.01	3
67		21	7	7	23.1	3	4	52.310	29	21	42.07	0.047	6.87	+ 0.043	0 69	5
68		24	6	44	38.3	3	15	16.316	28	7	1.75	− 0.178	7.21	− 0.002	0.57	3
69		29	7	49	48.5	3	33	19.649	26	2	16.72	+ 0.229	8.21	+ 0.060	0.15	3
70	Feb.	2	7	15	56.0	3	47	52.425	24	25	26.74	+ 0.032	9.04	0.021	+ 0.21	7
72		5	6	56	2.2	3	58	55.022	23	13	41.95	− 0.077	9.00	0.040	− 0.35	4
73		11	7	25	53.6	4	21	21.541	20	52	0.53	+ 0.094	9.69	0 048	0.31	7
74		12	7	17	53.8	4	25	4.779	20	29	1.74	0.052	9.70	0.006	0.66	7
75		14	7	57	56.2	4	32	40.099	+ 19	42	35.35	+ 0.259	+ 10.01	+ 0.013	− 0.70	7

of the orientation of the plate, and were partly corrected by the adjustment of the plate in the measuring machine. The remaining errors were adjusted by means of a least square solution of equations for each star of the form

$$a + bx + cy = n$$
$$\alpha + \beta x + \gamma y = \nu,$$

in which n is the difference between the computed and the observed $x \sec \delta_0$, and ν the corresponding difference for the y co-ordinates, a, b, c, α, β, and γ being unknown constants to be determined. This required for the 67 plates 134 least square solutions and, including a number of preliminary solutions in which the measures of the different images were reduced separately and a few plates which were measured a second time, the least square solutions numbered over 150.

As soon as the constants a, b, c, etc., were determined their values substituted in equations of the same form gave the corrections to be applied to the measured co ordinates of the stars and the planet in order to give the correct co-ordinates for the year 1900.0. These corrections to the star places agree remarkably well from plate to plate, showing that the star places obtained from the photographs are very exact. They also show by their smallness that the mean of the meridian circle observations at the thirteen observatories comes very near to the true position of a star. In very few cases is the difference as great as 1″.

It yet remains to convert the co-ordinates of the planet into differences of right ascension and declination, and apply them to the right ascension and declination of the center of the plate, reduce these for precession, nutation and aberration up to the moment of the observation, calculate the approximate parallax of Eros at that moment, assuming the solar parallax to be 8″.8, and the places of Eros are ready to be compared with the ephemeris of Professor Millosevich. All this takes but a minute to write but it took several days of very careful computation. The results are shown in Table I.

In this table the residuals in the two columns next to the last agree extremely well. We are accustomed in ordinary micrometric observations of asteroids to see differences of tenths of seconds of time and of several seconds of arc between residuals close together, but here they are only 2 or 3 hundredths of seconds of time and 1 or 2 tenths of seconds of arc.

TABLE II.

COMPARISON OF RESIDUALS IN RIGHT ASCENSION FROM THE PHOTOGRAPHS AT NORTHFIELD, PARIS AND BORDEAUX.

Date.	Gr. M. T. h	m	Parallax. s	Northfield. s	Paris. s	Bordeaux. s	Graphic Correction. s	v. s
Oct. 3	8	48	−0.957		−0.051		−0.060	+.009
	10	13	0.798		.044		.060	+.016
5	9	09	0.951		.074		.069	−.005
	16	49	0.827	−.071			.070	−.001
6	8	38	1.008		.048		.073	+.025
	10	51	0.685		.105		.073	−.032
8	10	46	0.700		.080		.083	+.003
9	11	07	0.614		.088		.089	+.001
	11	19	0.564		.090		.089	−.001
	14	59	1.141	.112			.090	.022
10	10	56	0.653		.103		.094	.009
	14	48	1.173	.103			.095	.008
	18	5	0.474	.097			.096	.009
11	13	59	1.245	.117			.101	−.016
	18	6	0.465	.099			.102	+.003
12	10	43	0.694		.113		106	−.007
	14	32	1.228	.107			.107	.000
	18	24	0.367	.086			.108	+.022
15	7	16	1.330			−.135	.125	−.010
	7	46	1.308			.112	.125	+.014
	15	58	+0.939			.144	.128	−.016
	16	18	1.019			.123	.128	+.005
	16	32	1.017		.129		.128	−.001
	16	50	1.132			.126	.128	+.002
	16	59	+1.096		.110		.128	.018
16	10	34	−0.702		.131		.133	+.002
	13	36	1.362	.144			.134	−.010
	17	19	.638	.113			.135	+.022
	17	53	.449	.139			.135	−.004
17	10	26	.729		.140		.140	.000
	11	11	− .509		.112		.141	+.029
	14	17	+ .512		.127		.142	.015
	15	12	.778		.134		.142	+.008
	16	11	+1.017		.171		.143	−.028
18	7	54	−1.349			.137	.149	+.012
	14	22	1.333	.154			.151	−.003
	17	31	0.542	.158			.154	−.003
19	7	9	1.420			.145	.158	+0.13
	7	30	1.399			.163	.158	−.005
	9	49	0.877		.154		.159	+.005
	14	04	−1.382	.175			.161	−.014
	14	29	+0.645		.138		.161	+.024
	15	29	0.926		.162		.161	−.001
	16	29	1.144		.128		.161	+.033
	16	30	1.209			.161	.161	.000
	16	51	+1.276			.149	.161	+.012
	18	33	−0.139	−.174			.162	−.012
20	8	22	−1.306			.177	.169	.008
21	16	24	+1.266			.194	.184	−.010
	16	45	1.332			.168	.185	+.017
	17	5	+1.388			−.211	.185	−.026
22	7	50	−1.288		.202		.192	.010
	8	10	1.236		.207		.192	.015
	10	40	0.586		.217		.193	.024
	11	0	−0.473		.197		.193	.004
	14	07	+0.642		.214		.194	.020
	15	07	0.943		.195		.194	.001
	16	09	+1.180		−.210		−.195	−.015

TABLE II.—Continued.

Date.	Gr. M. T. h	m	Parallax. s	Northfield. s	Paris. s	Bordeaux. s	Graphic Correction. s	v. s
Oct. 22	17	02	+ 1.415			— .190	— .196	+ .006
23	7	49	— 1.298		— .181		.204	0.23
	8	11	1.238		.178		.204	+ .026
	13	52	— 1.459	— .210			.206	— .005
	14	03	+ .660		.188		.206	+ .018
	15	3	.965		.208		.206	— .002
	16	3	1.205		.225		.207	.018
	18	41	+ 0.040	.222			.208	.014
24	7	40	— 1.453			.242	.215	— .027
	14	36	1.297	.217			.218	+ .001
	18	4	0.168	.226			.220	— .006
25	7	48	1.440			.240	.228	— .012
	13	49	— 1.487	.209			.230	+ .021
	16	15	+ 1.317		.248		.232	— .017
26	9	51	— 0.779		.230		.241	+ .011
	10	11	.666		.214		.241	.027
	13	35	— 1.530	.229			.242	.013
	13	53	+ .729		.220		.242	.022
	14	51	1.032		.230		.243	.013
	15	51	+ 1.277		.227		.243	.017
27	7	57	— 1.290		.247		.252	.005
	8	17	1.217		.233		.252	.019
	11	20	— 0.204		.248		.253	+ .005
	14	6	+ 0.845		.256		.255	— .001
	15	48	1.306		.250		.256	+ .006
	16	48	1.462		.264		.256	— .008
29	17	10	1.661			.293	.276	— .016
	17	28	+ 1.678			.261	.276	+ .015
30	6	30	— 1.660			.306	.280	— .026
	16	8	+ 1.476		.263		.284	+ .021
	16	50	1.665			.286	.285	— .001
	16	55	1.562		.277		.285	+ .008
	17	16	+ 1.696			.292	.285	— .007
Nov. 1	5	48	— 1.607		.278		.295	+ .017
	13	39	1.506	.275			.297	+ .022
2	13	10	— 1.639	.319			.304	— .015
3	16	51	+ 1.780			— .312	.309	.003
7	5	39	— 1.683		.328		.320	— .008
	7	48	1.219		.308		.320	+ .012
	8	8	1.108		.304		.320	.016
	9	4	0.748		.306		.320	.014
	9	29	— 0.574		.302		.320	.018
	11	7	+ 0.154		.291		.320	+ .029
	15	19	— 0.853	.347			.320	— .027
	5	47	1.670		.316		.322	+ .006
8	7	57	1.147		.329		.322	— .007
	8	41	0.873		.301		.322	+ .021
	9	38	0.475		.303		.322	+ .019
	14	57	0.983	.351			.323	— .028
10	5	36	1.697		.301		.334	+ .023
	10	24	— 0.035		.311		.324	.013
	10	33	+ 0.035		.311		.324	+ .013
	10	42	+ 0.104		.332		.324	— .008
	11	56	— 1.845	.255			.324	(+ .069)
11	6	10	1.596		.327		.326	— .001
	7	9	1.341		.329		.326	— .003
13	12	8	— 1.793	.283			.328	+ .045
	16	44	+ 1.789		.335		.328	— .007
	17	21	1.723		— .347		.328	— .019
	17	34	+ 0.525	— .314			— .328	+ .014

TABLE II.—Continued.

Date.	Gr. M. T. h m	Parallax. s	Northfield. s	Paris. s	Bordeaux. s	Graphic Correction. s	v. s
Nov. 13	23 46	+ 1.962	— .294			— .328	+ .043
14	23 30	1.888	.355			.329	— .026
	23 48	1.845	.321			.329	+ .008
15	10 11	0.092		— .319		.329	.010
	10 20	0.167		.319		.329	.010
	10 29	+ 0.238		.313		.329	+ .016
	11 48	— 1.842	.335			.329	— .006
22	12 45	— 1.402	.349			.334	.005
	23 22	+ 1.819	.345			.333	.012
24	12 18	— 1.509	.345			.328	— .017
26	13 49	— 0.791	.319			.323	+ .004
	16 27	+ 1.880			— .313	.323	+ .010
	23 23	+ 1.724	.348			.322	— .026
29	12 23	— 1.317	.308			.315	+ .007
	22 59	+ 1.760	.246			.314	.068
30	5 54	— 1.386			.288	.313	.025
	12 9	— 1.375	.280			.312	.032
	15 49	+ 1.916			.230	.312	.082
	16 12	+ 1.855			.205	.312	+ .107
Dec. 4	13 28	— .665	.363			.303	— .060
8	11 57	1.203	.271			.290	+ .019
11	11 46	1.194	.286			.282	— .004
12	12 1	— 1.067	.275			.280	+ .005
17	12 18	+ 1.695			.237	.266	.029
18	11 54	— 0.959	.260			.263	+ .003
	21 29	+ 1.698	.289			.261	— .028
19	11 44	— 1.007	.282			.260	.022
	12 16	+ 1.682			.260	.260	— .000
	13 19	1.805			.240	.259	+ .019
	14 23	1.791			.263	.259	— .004
	20 47	+ 1.781	.322			.259	(— .063)
20	13 35	— 0.158	.264			.257	— .007
21	12 17	— 0.734	.220			.254	+ .034
24	11 47	+ 1.576			.224	.246	.022
	12 23	1.680			.228	.246	+ .018
25	15 55	0.871	.281			.242	— .039
28	16 0	+ 0.999	.244			.234	— .010
31	12 9	— 0.616	.189			.225	+ .036
Jan. 1	11 49	0.736	.238			.222	— .016
2	12 3	— 0.628	.224			.210	.004
4	12 14	+ 1.580			.218	.214	— .004
	12 52	1.625			— 185	— .214	+ .029
5	11 36	1.481			+ .011	+ .030	— .019
	12 10	1.564			.021	.030	— .009
9	11 18	1.400			.090	.030	+ .060
	12 20	1.546			+ .052	.030	+ .022
14	11 23	1.380			— .013	.030	— .043
	11 53	+ 1.454			+ .006	.030	— .024
	12 4	— 0.495	+ .036			.030	+ .006
	12 34	+ 1.515			.066	.030	+ .036
15	11 59	— 0.521	.000			.030	— .030
18	12 6	— 0.451	.025			.030	.005
21	11 20	+ 1.313			.011	.030	.019
	12 10	+ 1.417			+ .010	.030	— .020
	13 7	— 0.047	+ .043			.030	+ .013
22	10 57	+ 1.237			— .005	.030	— .035
	11 22	+ 1.310			+ 0.003	.030	— .027
24	12 45	— 0.178	— .002			+ .030	— .032

TABLE II.—Continued.

Date.	Gr. M. T. h	m	Parallax. s	Northfield. s	Paris. s	Bordeaux. s	Graphic Correction. s	v. s
Jan. 29	13	50	+ 0.363	+ .060			+ .030	+ .030
Feb. 2	13	16	+ 0.032	.021			.030	— .009
5	12	56	— 0.077	.040			.030	+ .010
11	11	17	+ 1.119			— .037	.030	— .067
11	13	26	0.094	.048			.030	+ .018
12	13	18	0.052	.006			.030	— .024
13	10	37	0.999			+ 0.045	.030	+ .015
14	10	31	0.973			0.041	.030	+ .011
	13	58	0.259	+ .013			.030	— .017
21	9	42	0.759			0.046	.030	+ .017
22	9	0	0.590			0.063	.030	.033
23	11	30	+ 1.036			+ 0.048	+ 0.030	+ .018

In Table II I have put side by side the residuals in right ascension obtained from the photographs taken during the same interval of time at Northfield, Paris and Bordeaux, those of Paris and Bordeaux being the only photographic results which have as yet come to hand. These results were published in Circular No. 10 of the International Conference. The agreement of the three sets of residuals is on the whole quite satisfactory. In the diagram Fig. 7 I have platted these residuals from Oct. 3 to Nov. 15, the period during which the seeing seems to have been best at all the observatories. The numbers at the left end of the diagram are thousandths of seconds of time. The Northfield observations are represented by full black circles, those at Paris by open circles and those at Bordeaux by crosses. In this graphic way their relative accuracy and close agreement is well shown to the eye.

The reader must understand that the residuals are principally due to the errors of the elements of Eros' orbit, from which the ephemeris was computed. The third column of the table gives the amount of the parallax correction which was applied to the observation, and nowhere does the residual change sign, or even change by any marked amount, when the parallax correction changes sign. It is at once apparent that there can be no great correction to the assumed value 8.8″ of the solar parallax.

Up to this point I have endeavored to use as exact methods as I could employ. In what follows the process used is only approximate, but is as accurate as it is worth while to use in this preliminary investigation.

In order to eliminate the effect of the errors of the ephemeris I have drawn a smooth line as near as I could through the mean of all the platted points and have read off from this line the corrections for each date. These are entered in the column headed "graphic correction." The final residuals v are still vitiated to a slight extent by a possible correction to the ephemeris but con-

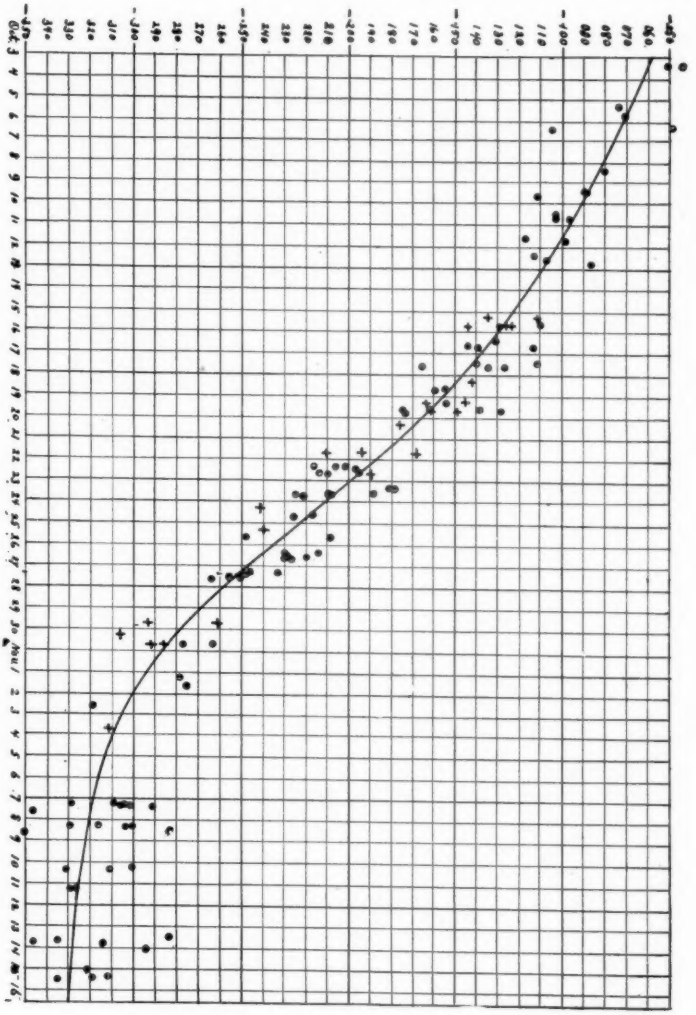


FIG. 7. GRAPHICAL COMPARISON OF THE RIGHT ASCENSIONS OF EROS FROM THE PHOTOGRAPHS AT NORTHFIELD, PARIS AND BORDEAUX.

sist mainly of accidental errors of the measures, and by taking the differences between suitable observations close together one may form equations which contain only the one unknown quantity besides the accidental errors. If we divide the numbers in the column headed "parallax" by 8″.8 we shall have the parallax factor or co-efficient, by which the correction to the parallax constant should be multiplied in each case. To save time we may regard $\frac{\Delta\pi}{8''.8}$ as the unknown sought and so take the numbers in the column of parallax as its co-efficients. Subtracting the co-efficients and residuals on Oct. 9 and 10 we will thus get the equation

$$0.667^s \frac{\Delta\pi}{8''.8} = +\ 0.013^s$$

In the following table are given all the similar equations which I could form from the Northfield results:

APPROXIMATE PARALLAX EQUATIONS, NORTHFIELD.

Date.		s		s		s		s
Oct.	9-10	0.667	$\frac{\Delta\pi}{8.8''}$ =	+ 0.013	Nov. 22	3 221	$\frac{\Delta\pi}{8.8''}$ =	— 0.007
	10-11	0.771	"	+ .007	26-26	2.515	"	— .030
	11-11	0.780	"	.019	29-29	3.077	"	+ .061
	11-12	0.763	"	.003	29-30	3.135	"	+ .036
	12-12	0.861	"	.022	Dec. 18-18	2.657	"	— .031
	16-16	0.818	"	+ .019	18-19	2.705	"	.006
	18-18	0.791	"	.000	19-19	2.788	"	.041
	18-19	0.840	"	+ .011	19-20	1.939	"	= — .058
	19-19	1.243	"	+ .002				
	23-23	1.499	"	— .009		22.037		+ .097
	23-24	1.337	"	.015				— .173
	24-24	1.129	"	.007				
	24-25	1.319	"	.027				— .076
Nov.	13-13	2.318	"	— .031				
	13-13	1.437	"	+ .020				
	14-15	3.708	"	= — .003				
		20.281		+ .116				
				— .092				
				+ .024				

Solution, Oct. 9-Nov. 15.

$$20.281 \frac{\Delta\pi}{8.8''} = +\ 0.024$$

$$\Delta\pi = +\ 0.010''$$

Solution, Oct. 9-Dec. 20.

$$42.418 \frac{\Delta\pi}{8.8''} = -\ 0.052$$

$$\Delta\pi = -\ 0.011''$$

Solving the equations from Oct. 9 to Nov. 15 gives for $\Delta\pi$, the correction to the assumed solar parallax, + 0″.010 or, taking the entire list, — 0″.011. It will be seen that if one of the large residuals were omitted the correction to the parallax constant would be changed by its entire amount, so that the above figures simply indicate the range within which it must lie, without giving its actual amount.

The following equations were obtained from the Paris and Bordeaux residuals in the same manner.

APPROXIMATE PARALLAX EQUATIONS, PARIS.

Date.	s		s	Date.	s		s
Oct. 15-16	1.758	$\frac{\Delta\pi}{8.8''} =$	+ .006	Nov. 7- 7	0.935	$\frac{\Delta\pi}{8.8''} =$	+ .022
17-17	1.241	"	+ .015	7- 7	0.645	"	+ .006
17-17	1.287	"	— .021	7- 7	1.262	"	.013
19-19	1.782	"	+ .014	7- 8	1.301	"	.036
22-22	1.904	"	— .008	8- 8	0.672	"	+ .026
22-22	1.529	"	+ .023	10-10	1.730	"	— .017
22-22	1.653	"	— .011	10-11	1.596	"	+ .014
23-23	2.090	"	.034	10-11	1.445	"	— .005
23-23	2.300	"	.041				
23-23	2.106	"	.015		47.140		+ .211
23-23	2.323	"	.037				— .276
25-26	2.039	"	— .037				
26-26	1.659	"	+ .007				— .065
26-26	1.820	"	— .012				
26-27	2.019	"	+ .017				
26-27	2.239	"	— .006				
26-27	1.481	"	+ .012				
27-27	2.135	"	— .006				
27-27	2.523	"	.013				
27-27	1.666	"	— .013				

Solution.

$$47.140 \frac{\Delta\pi}{8.8''} = - .065$$

$$\Delta\pi = - .012''$$

APPROXIMATE PARALLAX EQUATIONS, BORDEAUX.

Date.	s		s
Oct. 15-15	2.309	$\frac{\Delta\pi}{8.8''} =$	+ .005
15-15	2.440	"	— .012
19-19	2.629	"	— .013
19-19	2.675	"	+ .017
19-20	2.548	"	.014
20-21	2.630	"	.002
29-30	3.330	"	.026
30-30	3.340	"	+ .022
	21.901		+ .086
			— .025
			+ .061

Solution.

$$21.901 \frac{\Delta\pi}{8.8''} = + .061$$

$$\Delta\pi = + .024''$$

In the equations which follow, formed by combining the residuals of the different observatories on the same date, there may be systematic errors resulting from different methods of averaging the star-places obtained with the thirteen meridian circles. I took the arithmetical mean without assigning any weights, while at Paris and Bordeaux they must have assigned different weights to the different observations, for seldom do two of the three agree exactly on any star. The differences are of about the same magnitude as the final residuals for Eros and, although they are systematic for individual stars and for any one night, or perhaps two or three nights in succession, yet in the long run they may be regarded as accidental errors and so eliminated in average of a great number of equations. The comparison of 85 star places determined from the photographs at both Paris and

Northfield, and 123 determined at both Bordeaux and Northfield, gave as the average difference

Paris—Northfield in R. A. + .005^s, in Decl, + .003″
Bordeaux—Northfield " — .002 " + .003

APPROXIMATE PARALLAX EQUATIONS, PARIS-NORTHFIELD.

Date.	s		s		s		s
Oct. 9	0.577	$\frac{\Delta\pi}{8.8''}$ =	+ .021	Nov. 7	1.007	$\frac{\Delta\pi}{8.8''}$ =	+ .056
12	0.534	"	— .007	13	3.582	"	— .052
16	0.660	"	+ .022	13	1.198	"	— .033
19	2.287	"	.033	15	2.080	"	+ .022
23	2.271	"	+ .013				
23	1.165	"	— .004		21.572		+ .187
25	2.804	"	— .038				— .134
26	0.864	"	+ .014				
26	2.543	"	+ .006				+ .053

Solution.

$$21.572\ \frac{\Delta\pi}{8.8''} = + .053$$

$$\Delta\pi = + .022'',$$

APPROXIMATE PARALLAX EQUATIONS, BORDEAUX-NORTHFIELD.

Date.	s		s
Oct. 19	1.380	$\frac{\Delta\pi}{8.8''}$ =	+ .018
Nov. 26	2.671	"	+ .006
Dec. 19	2.689	"	+ .022
Jan. 14	1.949	"	— .030
14	2.000	"	+ .030
21	1.412	"	— .033
Feb. 14	0.714	"	+ .028
	12.815		+ .104
			— .063
			+ .041

Solution.

$$12.815\ \frac{\Delta\pi}{8.8''} = + .041$$

$$\Delta\pi = + .028''$$

If now we take the arithmetical mean of the five different values of $\Delta\pi$ which have been obtained we shall get $\Delta\pi = + 0.010''$, with a probable error of $\pm$ 0.006″. If we give the different values weights in proportion to the co-efficients of the final equations from which they were derived, we shall get $\Delta\pi = + 0.002''$ $\pm$ 0.006″.

The only conclusion which we can draw from these results is that the solar parallax is very near to 8,80″, probably between that and 8.81″. It would not be worth while to undertake a rigorous solution of these equations alone, for it is necessary to get together a much greater mass of observations in order to more completely eliminate the accidental errors.

I have made a similar study of the residuals in declination and find that they give a larger positive correction to the parallax, but the co-efficients are too small to give them much weight in comparison with the right ascension residuals.

It is interesting to note that the results obtained above from the right ascension residuals agree very closely with those obtained by Dr. Gill, of the Cape Observatory, from Heliometer measures of the asteroids Victoria and Sappho in 1889. In fact the value 8.802″ is identical to the last figure with the most probable value found by Dr. Gill, and the probable error resulting from the approximate method which I have used is less than 0.001″ greater than his. We may therefore confidently expect that, when all the observations at forty or more observatories are combined by the most refined methods, the solar parallax will be determined more accurately than ever before.

If we assume 8.80″ as the correct parallax of the Sun, and 3963.3 miles as the equatorial radius of the Earth, the Sun's distance is given by the proportion

$$d : 3963.3 :: 1 : 8.80 \sin 1'',$$

which solved gives $d = 92{,}897{,}000$ miles. If the parallax should be increased to 8.81″ the distance would be decreased by 106,000 miles. There is still therefore an uncertainty of about 60,000 miles in the Sun's distance. This uncertainty we may perhaps expect to be diminished by half when the final result is obtained from the Eros observations of 1900-1901.

WHAT WOMEN HAVE DONE FOR ASTRONOMY IN THE UNITED STATES.

ANNE P. McKENNEY.

FOR POPULAR ASTRONOMY.

The United States of America is a large country with large hearted and liberal minded people. There is no other country in the world where women, as a class, have advanced so rapidly. In their studies they encounter very little narrow mindedness and jealousy among their fellow-workers in the same field of research, but, in general, are treated with the greatest courtesy, encouragement and assistance. While we cannot maintain that in everything woman is man's equal, yet in many fields of work her patience, perseverance and method make her his superior.

In no line of work has her influence been felt more than in the field of astronomy. A review of the progress of astronomical research during the past century is incomplete without a distinct recognition of woman's activity in furthering the science, not only by actual work but also by substantial pecuniary assistance.

Maria Mitchell: the first American woman astronomer, was

born on the island of Nantucket, Mass., August 1, 1818, of a Quaker family. She was raised in an intelligent home where topics of the day were fully discussed. Matters of science received special attention. Her father owned an excellent telescope and was himself a very good astronomer, being able to carry on independent observations. Miss Mitchell early displayed her delight in astronomy. She was her father's apt pupil, supplementing his instruction with diligent study. At eighteen she became librarian of the Nantucket Athenaeum, which place she held for twenty years. During this time she pursued her scientific studies with great ardor. In 1847 her patient work was rewarded by the discovery of a new comet, for this, Frederick of Denmark rewarded her with a gold medal. The Cantons of Switzerland voted her a similar recognition of her services. She was subsequently employed by the government to do much difficult mathematical work on the coast survey and also helped in the preparation of the "American Nautical Almanac." In 1857 she went abroad and made the tour of the celebrated observatories of Europe. Here she was given a hearty welcome by foreign astronomers and her abilities recognized and honored by membership in many scientific societies being conferred upon her. Her fame early opened for her all the doors in social as well as scientific circles.

During her absence in Europe, her American friends, under the leadership of Elizabeth Peabody of Boston, built an observatory for her use in Nantucket and fitted it with a fine telescope. Here she pursued her investigations until Vassar College was opened in 1865, when she was called to the professorship of Astronomy in that institution and was also given the directorship of the Vassar Observatory. She at once demonstrated her abilities as a teacher, and her earnestness and simplicity were not without their effect on the college at large. While at Vassar she made observations of the surface details of Jupiter and Saturn, and of the positions of their satellites. She made also many other observations of comets, etc. Her main force, however, went into teaching. In 1888 she resigned her position in the college owing to ill health and advancing years, and wishing to devote herself to special investigation. After leaving Vassar she returned to her family in Lynn, Mass. There she had moved her astronomical instruments. She was the first of her sex elected to membership by the American Academy of Arts and Sciences. American Colleges conferred degrees upon her. For several years she edited the astronomical notes in the *Scientific American* which were based on calculations made by her students. She died at Lynn,

Mass., June 28, 1889.

Williamina Paton Fleming: was born in Dundee, Scotland, May 15, 1857. She was the daughter of Robert Stevens, a picture dealer. She received her early education in her native town in the public schools, in which she subsequently taught for five years. In 1877 she married James Orr Fleming of Dundee, Scotland.

On coming to the United States she became connected with the Harvard Observatory, one department of which she is at present in charge. Beginning with the simplest forms of computations the responsibility of her position increased every year, until now she has a splendid record as an astronomer. She has charge of a corps of women assistants by whom the stars are studied in the daytime by the aid of photography, in the same way as by night through the telescope, and by whom the observations made by the meridian photometer since 1888 have been discussed. Mrs. Fleming from her examination of the spectra of stars, of which she has examined over a million, has achieved distinction as a discoverer, having increased the number of known stars whose spectrum is of the third type, from about 1,000 to 3,000; while of the rare class of stars of the fifth type the number has been raised from 16 to 67. "At no other observatory have any stars of the last mentioned class been discovered, during the last eleven years" says Professor Pickering. She has furthermore discovered 54 *new* variable stars by means of the bright hydrogen lines in their spectra, and in each case has proved their variability from photographic charts of the same regions. In 1890 she was able to announce, from its spectrum, that a certain star in the constellation Cygnus was variable. She also has the honor of having first discovered planetary nebulæ by the aid of photography, while in 1893 and 1895 she made the remarkable discoveries of new stars in the constellations Norma and Carina. Besides numerous contributions to astronomical periodicals she has aided in the preparation of several volumes of the *Annals of the Observatory;* Her signature has appeared from time to time in the *Astronomische Nachrichten* and other astronomical journals. Her name is well known among European scientists. *The Observatory* has called her a brilliant discoverer.

Alice Lamb: now Mrs. Milton Updegraff was assistant astronomer in the Washburn Observatory from June 1885 to September 1887. Here she had charge of the extensive time service of the Observatory, and also took part in the regular series of observations with the Repsold meridian circle. She made many

observations of the minor planets and double stars with the 15.5 inch equatorial telescope. In September 1887 she married Professor Updegraff and went with him to the Argentine Republic where they both served as astronomers in the National Observatory from November 1887 to March 1890. She had charge of the time service there.

Since returning to the United States she has retained her interest in astronomy and is now preparing for publication a translation of Ruhlmann's "Barometrische Hohemessengen."

Dorothea Klumpke: was born in San Francisco, but left there in her youth and spent several years in Germany, Switzerland and Paris. In 1887 she was a student at the Observatory of Paris, and acted as a translator for the first Astrophotographic Congress which convened in 1887. Her observations of several minor planets and of the Tempel-Swift comet have been published. On December 23, 1893, Miss Klumpke sustained her doctorate thesis before Darbonx Jesse and Andoyer. It was a purely theoretical study of the rings of Saturn. At the conclusion of the examination Darbonx remarked "Your thesis is the first which a woman has presented and successfully maintained with our faculty to obtain the degree of doctor of mathematical sciences. You worthily open the way, and the faculty votes unanimously to declare you worthy of obtaining the degree of 'doctor.'" Dr. Klumpke is now at the head of the bureau for the measurements of the plates of the Astro-photographic Catalogue at the Paris Observatory.

Charlotte R. Willard: graduated at Smith in 1887. There she specialized in astronomy and mathematics. After graduation she accepted a position as assistant at Goodsell Observatory, Northfield, Minn. Here under the direction of Professor Payne she took charge of the time service which is one of the most extensive in this country covering a distance of 13,000 miles. At 9.57 A. M. the signal goes out, all the switches along the line are turned off, these messages having precedence. By means of a small key attached to necessary wires Miss Willard sent out her record of time over the country. Besides this work she occupied for a long time the position of teacher of mathematics at the same place. In 1893 Miss Willard went to Marsovan, Turkey, to teach in the girls' school there. After a few years of work an epidemic of smallpox broke out to which Miss King of Minneapolis, also a teacher, fell a victim, in spite of diligent nursing and the utmost care on the part of her companions she died. Miss Willard took her place and was very successful in her

work. Miss Willard's writings on astronomy are confined for the most part to articles which have appeared from time to time in POPULAR ASTRONOMY of which she was assistant editor for several years.

Mary Emma Byrd: graduated from the University of Michigan and also from Smith College. For several years she was employed as teacher in a high school. Later she was called to the Observatory at Harvard where she remained for one year. From there she went to Goodsell Observatory at Northfield, Minn. She was employed there for four years until called to the Observatory at Smith College, Northampton, Mass. There she was instructor in mathematics and astronomy and is now Director of the Observatory in that place. Her method is the laboratory method. She says "laborious investigations necessitating telescopes and Observatories are not ones which should engage the attention of the average student at the beginning, but rather the simple observations which teach them how to see and enable them to gather at first hand a store of pleasant astronomical information." She published in 1899 "A Laboratory Manual in Astronomy."

Susan J. Cunningham: is Director of the Observatory of Swarthmore College, Swarthmore, Penn., and also mathematical assistant there. At the beginning of her work she was engaged for a year at Vassar. From there she went abroad and studied in Germany, London and Cambridge. On her return to this country she went to the Lick Observatory, where she remained for some time.

On her return East she visited the Harvard Observatory and did some work there. Her work at Swarthmore is interesting, particularly her experiments with the seismograph, an instrument for recording earth-quakes, and announcing their approach. Her instrument recorded the great earth-quake in the Hawaiian Islands some years ago.

Mrs. Elizabeth Davis: studied mathematics and astronomy at the Johns Hopkins University, Baltimore, Md. Here she met Professor Davis, an astronomer, whom she afterwards married. She was interested in mathematical calculations, but her principal work was her calculations for a number of years and even at the present of the Ephemeres of the Sun for the Nautical Almanac. She also did some miscellaneous work on comet-orbits. From time to time she has done work at the Observatories of Yale, Smith and Goodsell. She at one time held the position of professor of mathematics at the Naval Observatory at Washington.

F. Gertrude Wentworth: graduated from the Boston Universiry. Her work has been for the most part in the direction of astronomical computation of a difficult and refined order, involving a capacity and accomplishment far beyond that required by some of the merely mechanical work. She combines an intelligent appreciation with an expertness in the conduct of elaborate numerical processes of the higher practical astronomy. Her work has not been original or direct and independent investigation, but she has far greater capacity for it than many men who attempt it. Professor S. C. Chandler of Cambridge says of her "She is the most trustworthy computer I ever knew, man or woman." She has contributed several papers to the various astronomical publications.

Rose O'Halloran: represents very well the work done in astronomy by women in the West. She was born in San Francisco, Cal., and has conducted much of her work there. She is known to the world through her numerous articles on the observations of eclipses, meteors, variable stars, etc., which frequently appear in POPULAR ASTRONOMY and other periodicals.

Perhaps the best work done by women is that done in connection with the leading Observatories of the East where women are employed, namely at Vassar, Wellesley, Harvard and Columbia.

The Observatory at Vassar College was built and equipped by the Trustees. The officers are employed primarily for the purposes of instruction, any independent work being entirely voluntary. The first director was Maria Mitchell from 1865 to 1888. Her principal work while there was the observation of the surface details of Jupiter and Saturn and the position of their satellites. She also made observations of different comets. Her main force, however, went into teaching. She was succeeded in 1888 by Professor Mary W. Whitney, her pupil and associate. Miss Whitney began the systematic observations of comets with a filar micrometer and the 12-inch equatorial. She published her observations in 1890, 1892, 1895, etc., in the *Astronomical Journal.* She had no regular assistant until 1895 when Miss Caroline Furness, a pupil of hers was appointed to the position. Miss Furness later went to Columbia, where in 1899 she took her Doctor's degree in astronomy under Professor John K. Rees. Miss Whitney together with Miss Furness began observations of minor planets. The result of these observations were published in the *Astronomical Journal* and in the *Astronomische Nachrichten.* They also published observations of occultations at the

times of the lunar eclipses which appeared in POPULAR ASTRONOMY. Within the past few years the Observatory has undertaken the measurement and reduction of astronomical photographs. The special problem investigated is the cataloguing of stars within 1° of the North pole. The work was executed with the advice and at the suggestion of Professor Jacoby of Columbia University, who provided the necessary plates. A discussion of a further series of plates covering 1° to 20° from the pole is now in progress.

From time to time there have been graduate students who have taken part in the regular observational work. Mary Tarbox published observations of minor planets and is now employed at Columbia University. Alice Davis now Secretary and Librarian at the Allegheny Observatory also published observations of minor planets. Margaret Palmer, computer at Yale, received her astronomical training at Vassar, also Antonia Maurey, who is working in spectroscopic astronomy at Harvard. At present there are three graduate students at the Observatory. One is working on the definitive orbit of a comet, the other one on variable stars. They also published the Ephemerides of long period variables in POPULAR ASTRONOMY every month during 1903. In general the work done at Vassar is similar to that done at several of the smaller German and Italian Observatories.

The Observatory at Wellesley was built and equipped by the enlightened liberality of one of the Trustees, Mrs. John C. Whiten. It has been completed but a few years and therefore, as yet, the record of its astronomical day is short. Special emphasis is laid here upon spectroscopic astronomy; the observation and mapping of spectra gases; the study of spectrum maps and finally the study of star spectra. In the uncertainty of the weather the study and measurement of photographs as applied to all the problems of astronomy is found valuable. The above work is included in the general course in Physical and Descriptive Astronomy of which Miss Sarah F. Whiting, a pupil of Professor Pickering of Harvard, is in charge. The mathematical astronomy is in charge of Miss Ellen Hayes, Professor of applied mathematics. The students in this department take appropriate observations and furnish data for their work in time latitude and orbits. As yet the professors have had no time for outside work, but the field open to them in the future is a broad one. Miss Annie J. Cannon, a pupil of Miss Whitney's, has lately published a volumn of annals on the classification of the smaller stars by their spectra. She has also done continuous work on variable

stars. While employed at the Harvard Observatory she made a detailed study of the spectra of bright southern stars.

The application of photography to astronomy has wonderfully increased the opportunities for women. The most extended application of the aid of women in this speciality has been under the Directorship of Professor Edward Pickering at the Harvard Observatory where a large force of women are constantly employed under the supervision of Mrs. Williamina Fleming. She is in charge of the department for the examination of views and of photographic plates taken with the Draper telescope. In the course of this examination Mrs. Fleming has made a large number of discoveries of variables and has confirmed the discovery of several new stars. Mrs. Fleming is ably assisted in this work by Miss E. F. Leland and Miss A. C. Maury who have made a detailed study of the spectra of the bright northern stars, also by Miss M. C. Stevens and Miss L. D. Wells, all of whom are women having more than one discovery to their individual credit. The Observatory has a corps of about forty assistants, seventeen of whom are women, twelve of these are engaged more or less on photographic work.

Photographs obtained with the various telescopes now in use at the Harvard Observatory are of various classes. The most important of these are chart plates having exposures of from ten to sixty minutes; spectrum plates having the same exposure and heat plates having several exposures of a few seconds duration.

Women assistants are not engaged during the night in taking photographs, but find their time during the day sufficiently occupied in examining, measuring and discussing them and in the various computations therein involved.

The most important work at present along this line is being done from the chart plates taken with the eight-inch Draper telescope. This consists in the measurement of stars for standards of stellar magnitudes. Measurement of about forty thousand plates are now being made by Miss Eva F. Leland, Miss L. D. Wells and Miss C. S. Stevens and have shown great accuracy in making the identification of stars shown in the photographs with those contained in existing catalogues.

Photographs of stellar spectra are all carefully examined in order to detect new objects of interest such as 3rd, 4th and 5th type stars or those whose spectra consists mainly of bright lines.

Many interesting discoveries have been made from the study of these photographs of stellar spectra. First in importance was the discovery made by Professor Pickering that Ursa Major is a

close binary star the components revolving around each other at a velocity of about 100 miles a second in a period of about fifty-two days. This discovery led to the finding of a second object of this class, namely Aurigæ by Miss A. C. Maury. Micrometric measurements of the lines in the photographic spectra of the bright stars have been made by Miss Florence Cushman. From an examination of the photographs of stellar spectra, thirty-eight stars having spectra of the fifty type have been added to the sixteen previously known, making the number now known forty-four in all.

About six or eight years ago an astronomical bureau was started at Columbia University, New York City, under the direction of Professor J. K. Rees, Miss Flora E. Harpman, a graduate of Carleton College, but then an assistant at the Smith College Observatory, Northampton, Mass., was called there as head computer. It has developed until it is now one of the most trustworthy and accurate calculating and computing means in the country. Miss Harpman is ably assisted by Miss Magill of Swarthmore College, and Miss Tarbox and Miss Davis both of Vassar.

Over thirty years ago Lewis M. Rutherford began in New York City his experiments in astronomical astronomy. He continued his work for over twenty years. His best photographs were taken with a refracting equatorial corrected for chemical rays of light. This telescope was 11¼ inches in aperture and had two object glasses, one for seeing and the other for photographing. He used wet plates entirely. Mr. Rutherford devised and constructed his own machine for measuring the star plates. This was arranged so as to measure the position, angle, and distance of every star on a plate from a known central star. In 1890 Mr. Rutherford gave all his best negatives to Columbia University. When this collection of negatives was turned over to the Observatory it was arranged to have the work of reduction of the measurements of the star plates pushed forward as rapidly as possible. Mr. Harold Jacoby, assistant at the Observatory, undertook the reduction of the Pleiades plates. Rutherford Stuyvesant, son of Mr. Rutherford, although not interested in science himself, gives $1,000 every year to defray the expense of reduction and publication of results of the Rutherford negatives. The women computers have charge of this work.

Notwithstanding the various way in which the preceding sketches reveal woman's application of thought and energy to the cultivation of astronomy, nothing has been of such aid to its

development as the unbounded liberality of some of our American women. The most notable patronesses are Mrs. Henry Draper, of New York City, Miss Catherine Bruce, of New York City, and Miss Alice Bache Gould, of Boston.

Dr. Henry Draper in 1872 was the first to photograph the lines of a stellar spectrum. His investigation, pursued for many years with great skill and ingenuity, was most unfortunately interrupted in 1882 by his death. Early in 1886 Mrs. Draper made a liberal provision for carrying on this investigation at the Harvard Observatory under the direction of Professor E. C. Pickering as a memorial to her husband. She gave several instruments and contributes $10,000 annually for the work of this department. Owing to the extensive field of investigation in this branch of astronomical physics Mrs. Draper has decided to greatly extend the original plan of work, and to have it conducted on a scale suitable to its importance. In this work Dr. Draper's 11-inch photographic lens is used, for which Mrs. Draper has provided a new mounting and Observatory. There are also at Cambridge a 28-inch reflector and its mounting, also a 15-inch mirror, both gifts of Mrs. Draper. In the Observatory there is a central room where the comparison of charts and photographs is carried on. This is known as "The Draper Memorial Room."

The most unbounded liberality so universally bestowed by Miss Catherine Bruce upon every branch of astronomy in all parts of the world will make her name go down in future ages as worthy of unlimited admiration. One can hardly pick up an astronomical publication in these days without finding a mention of some new gift from her to astronomy,—$250 to purchase a small instrument for a zealous astronomer in a far away island of the sea; $25,000 to aid in the removal of a vast Observatory to a better location; $15,000 to pay for printing various valuable astronomical researches; $50,000 to purchase a new photographic telescope. These are but a small portion of her benefactions bestowed with so much wisdom as to make the first gift no less acceptable than the last. Miss Bruce has been called "the Maecenus of Astronomy." Her intelligent generosity knew no limits of race or country. Her kind and thoughtful care lightened many a burden in her own land and helped to finish many a task where patience and other resources were nearly gone. To Professor Max Wolf at Heidelberg she gave $10,000 for a telescope. With this instrument he discovered a new asteroid and named it "Brucia" in honor of Miss Bruce.

Harvard and Columbia seem to have been the institutions

which have gained most through Miss Bruce's liberality. To the former, from time to time, she gave $50,500, and to the latter $14,100. Her donations to astronomy in ten years from June 1889 to Nov. 29, 1899, amounted to $174,275.

Miss Bruce was born January 22, 1816. Her home was in New York City, where she died March 13, 1900. She was a daughter of George Bruce, the famous type founder. She was an accomplished woman, having a knowledge of Latin, Greek, French and Italian. She was for many years an invalid. She has left a gracious memory of good and generous deeds and an impressive example of noble womanhood.

Miss Alice Bache Gould was educated at Bryn Mawr College, Penn. After graduation she went to Cambridge, England, where she took a degree at Girton College. After her return home she became instructor in mathematics first at Carleton College, Northfield, Minn., and afterwards at Chicago University.

She has written a book on some extensions of Euclidean geometry, also a life of Louis Agassiz, which authorities regard as the best that has appeared notwithstanding its small compass. She is a woman of high intellectual caliber, most discriminating taste and judgment, and a lovable character.

On November 17, 1897, she gave the sum of $20,000 to the National Academy of Sciences as trustee, to establish a fund to be known as "The Benjamin Apthorp Gould Fund," in memory of her father. The income was to be used to assist the prosecution of researches in astronomy. The administration of this income in accordance with the terms of the trust and of a letter of instruction from the donor, was placed under the direction of Louis Boss, Seth C. Chandler and Asaph Hall.

"The object of this fund is first to advance the science of astronomy, and secondly to honor the memory of Dr. Gould by ensuring that his power to accomplish scientific work shall not end with his death. In recognition of the fact that during Dr. Gould's life-time his patriotic feeling and ambition to promote the progress of his chosen science were closely associated, it is preferred that the fund should be used primarily for the benefit of investigators in his own country and of his own nationality. But it is further recognized both by the donor and by the directors that sometimes the best possible service to American Science is the maintenance of close communion between the scientific men of Europe and America, and therefore, even while acting in the spirit of the above restriction, it may occasionally be best to apply the money to the aid of a foreign investigator working

abroad."

The wish was also expressed by the donor that in all cases work in the astronomy of precision should be given the preference over work in astrophysics, both because of Dr. Gould's predilection and because of the present existence of generous endowments for astrophysics. "Finally the B. A. Gould Fund is intended for the advancement and not for the diffusion of scientific knowledge. And is to be used to defray the actual expenses of investigation rather than for the personal support of the investigator during the time of his researches without excluding the latter use under the most exceptional circumstances."

(C. F. Report of B. A. Gould Fund).

Whatever women may be capable of, individual cases at least show that she can do much and do it remarkably well when her enthusiasm is thoroughly aroused. In all cases under our notice there has been present to a wonderful extent, devotion, patience, persistence, generosity, to which has been added in some instances, a deep intellectuality. Therefore let us hope that in astronomy, which now offers a large field for woman's work and skill, she may, as has been the case in several other sciences, at least prove herself man's equal.

December 30, 1903.

MAGNE-CRYSTALLIC ACTION AND THE AURORA.

M. A. VEEDER.

For Popular Astronomy.

Magne-crystallic action plays an important part in determining the location of auroral clouds, arches, streamers, and bands, and their coloration. The ice crystals of the upper atmosphere assume the shape exclusively of hexagonal prisms, and all crystallic bodies of such sort tend to place themselves with their axes parallel, or perpendicular, to lines of magnetic force, according as they are paramagnetic, or diamagnetic, in their behavior. Thus these prisms of ice must assume definite positions in reference to currents of electricity constantly, or fitfully, traversing the atmosphere. In the case of a current following a stratum of air that is homogeneous, as is most apt to occur in a horizontal direction, these prisms, if diamagnetic, will have their axes vertical, no matter what may be the position of others in strata adjoining. Thus there is an arrangement similar in principle to that employed in the prismatic lenses and reflectors in light-

houses, to concentrate the light in particular directions. In the case of crystals floating in the air in cloud-like forms, and behaving somewhat differently, it may be, in strata at different elevations, and differently electrified, there will be interferences and irregularities, and composite effects, but nevertheless so long as the angles of reflection and refraction involved remain the same there will be concentration of effect in certain definite directions from the source of luminosity, just as appears in the case of halos about the Sun and Moon, which are produced in this very way. Hence it is not possible to determine the position in space of the source of auroral light, by simply taking the apparent height of arches and streamers. As in the case of the rainbow every observer sees his own arch, or streamer, and furthermore every auroral arch, like a halo, must be seen at an angle of twenty-two, or forty-six, or even ninety degrees from the direction of the source of the light which originates it. There are chromatic diffraction effects apparent in certain cases also, which afford additional evidence that the features of the aurora under consideration are originated in precisely the same way as the halo. In the case of the aurora the problem is complicated by the cloud-like distribution, more or less widely diffused, of the source of light, it not being such a source of illumination, definitely circumscribed, and of definite size, as are the Sun and Moon in the production of the ordinary halo. Consequently there may be reduplication of arches where an auroral cloud splits into two or more parts, each having its own arch-producing effect at its own proper angle of refraction. Such irregularity in auroral cloud-forms that are specially brilliant, and well defined, may transform the resultant arches into curtains. So an arch is sometimes seen slightly flattened, or of elliptical shape, or very much thickened at some one part. Rarely an arch has been seen forming a complete ellipse not extending below the horizon. More frequently however a portion only of such an ellipse is seen distorted into the form of a curtain. Attendant upon such refraction there is, as in the case of the halo, more or less coloration. It is likely however, that the deep red color of the aurora seen at times is due to the electric currents traversing the more rarefied strata of the upper atmosphere, coloration of this particular type appearing when an electric current is transmitted through a vacuum tube from which the air is nearly exhausted. Superadded to all these forms of luminosity and coloration there is the effect of reflection from the outer surfaces of the ice crystals floating in the air. These crystals having their major axes parallel with each

other, and the surfaces corresponding to their remaining axes at all possible angles with each other; the effect of reflection from the lateral surfaces thus arranged is to transform a spot of light into an elongated streak; thus, originating streamers, especially in the vicinity of arches and auroral clouds, and having the colors of such arches and clouds. Thus in order to determine the position of the source of auroral luminosity in space it is necessary to take into the account the magne-crystallic action of ice particles in the upper atmosphere as determining the distribution of light by refraction and reflection.

The writer has noted instances in which the non-appearance, or very faint appearance of an aurora that was brilliant at the same or even lower latitude a few hundred miles away has been due apparently to absence of the atmospheric conditions on which the formation of high cirrus cloud composed of ice crystals depends. Also certain displacements of auroral phenomena from the magnetic meridian, or the magnetic zenith, may be the effect of refraction or reflection of light alone in the manner that has been described. It is to be noted however that after due allowance has been made for such reflection and refraction there are displacements due to the nature of the electrical forces involved, a temporary magnetic pole being developed by induction from the Sun, thus causing auroral luminosity to originate at points somewhat removed from the permanent magnetic pole of the Earth. In order to understand from the behavior of the aurora the play of the electrical forces involved it is necessary as a preliminary step to clear up the subject of magne-crystallic action, about which so far as the writer is informed not a word has been written in this connection, the theory of the halo, as well as that of the aurora, being incomplete in this regard. That there is such a phenomenon as magne-crystallic action appears in the text books on Physics generally, but its application to the case under consideration has not been made, and it would seem to be a very serious omission.

LYONS, N. Y., Jan. 16th, 1904.

VENUS, 1903.

PERCIVAL LOWELL.

In 1903 I observed Venus from February 18 to July 25. In view of the difficulty of the subject, and of the possibility of psychical illusion in the case, I took special care against self-de-

ception in my scrutiny of the markings presented by the disk. Nothing was set down without a caveat until I had assured myself of the certainty of its non-subjective existence. Two points I examined specifically: one the objective assurance of the psychical perception; the other the space-prolongation of an impression by movement of the eye. With regard to the first point, experiments on the visibility of a wire* show that it is possible by direct consciousness to part the true from the spurious. Although it is possible to see illusory lines, it is also possible to become cognizant of the fact. If one pay attention, an hallucination of the sort may be found to differ from a presentation of fact by the absence of the sense of reality. I am speaking, of course, only of one kind of hallucination, upon which I have myself made experiments. A peculiar consciousness of objectivity accompanies an impression started from without which is wanting in one originated from within. Upon such direct consciousness we rely, indeed, in all our relations of life. With regard to the second kind of illusion, the transference of a perception from one point to another by motion of the eye, experiments have led me to believe in the possibility of its production at times near the limit of vision. Whether the transference is due to continuity of impression, for the eye retains an impression for the twentieth of a second, and might thus conceivably superpose a first image upon a second part of the field, or whether it be an ideo-sympathetic effect, I am not aware, nor is it for our purpose vital to inquire. That it may be produced, and that it may also be precluded by holding the eye still is sufficient. This plan I adopted. It is not so easy as one might imagine; for bent on detection, the eye has a roving drift hard to hold in check.

Of the markings to be made out upon the disk, there are two kinds. The nicks in from the terminator, the collar round the south pole, and the two spots upon it, like beads upon a necklace, belong to the first and most obvious class. Of them I have never entertained the suspicion of a doubt, and they alone are sufficient to show that the planet's rotation is an affair of about 225 days. To the second, and more difficult kind, belong the long shades which starting from the terminator seek the center of the disk. These, both from their faintness and from their suspicious configuration, are more open to question, and demand the most critical attention. It is they that have most to tell us of the planet's present surface conditions.

* Lowell Observatory, Bulletin No. 2.

The observations of 1903 were confirmatory, to the extent of their detection, of both classes and reaffirmed the existence of many of the markings seen before in 1896-7 and 1901. Of the first class, the south polar collar and the two spots, Astoreth and Ashera, which figured in the map of the planet I made in 1897, showed much as they had showed then. The tooth-like shadings denting the terminator at the outer ends of Anchises' regio and Hero regio were likewise once more noticeable. So that the markings, in which illusion of the kind suspected was not concerned, asserted thus their objective existence. With regard to the other sort the proof of actuality was two-fold. In the first place, the lines making in from the terminator which constitute the spokes of the above singular configuration, appeared again in the same places they had occupied in 1897 and 1901. This alone is very strong evidence of their reality. In the next place, these markings came out at times with a definiteness to convince the beholder of an objectiveness beyond the possibility of illusion. Instances of this I shall now quote from my notes:

March 22, $13^h\ 55^m$. "Never felt more sure of the reality of the markings (Anchises and Hero, as well as the collar and its two spots)."

April 13, $12^h\ 44^m$. "This marking (Hero) is unmistakable. It came out in a way that could not have been an optical training in from the rim; as it were all together."

The point here is the preclusion of the effect on the retina of prolongation of a nick on the terminator on to the disk by a rapid motion of the eye. Again:

April 13, $13^h\ 08^m$. "These markings (Anchises and Hero) are as sure as markings can be."

April 14, $7^h\ 18^m$. "Tried to keep the eye from running in from the terminator, and in this manner saw the lower marking (Hero)."

April 14, $12^h\ 52^m$. "The lower marking comes when I keep my attention on the center of the disk—(I) try and succeed in not letting the eye strike in from the terminator."

April 24, $13^h\ 00^m$. "The collar south seen with absolute certainty as reality, seeing 7."

April 30, $13^h\ 00^m$. "Seeing 7, collar beautifully seen."

May 18, $13^h\ 02^m$. "South collar again, certainly there. Also dark tooth at north."

May 22, $12^h\ 38^m$ to 49^m. "The markings come out like an etching. No illusion effect whatever."

May 27, $13^h\pm$. "Find on turning to Mars the details of that planet not so sharp as those of Venus were, but Mars is fainter and not so high up."

June 30, $11^h\ 52^m$. "At first glance one sees the notches in below the cusps. There is nothing analogous the case with the Moon to the naked eye. Therefore they are not optical effects."

All the above observations in Greenwich mean time.

A condition affecting the visibility of the markings which I had

noticed in 1896-7 was again apparent: The phase shown by the disk at the time. The nearer the disk is to the full, the easier the markings are to make out. This peculiarity is independent of the altitude at which the planet be observed. So that it is here not question of terrestrial conditions, but of the verticality or obliqueness of illumination of the Venusian surface. The more vertical the Sun the easier it is to see the features of the planet. For this reason apparently certain markings pass from view as they pass from the center of the disk, while others before invisible emerge to sight as they near that point.

In pursuance of this principle it is imperative in the comparison of drawings to consider only those made under like phase. If this be done with the picturings of the planet made by Schiaparelli on December 9, 14 and 21, 1877,* July 5† and July 30‡, 1895, and with that of Fig. 4 of this paper made June 23, 12^h 5^m, G. M. T., 1903, a very striking agreement will be perceived, an agreement so close as to carry instant conviction of a depicting of actuality to an unprejudiced mind. The collar, composed of the markings called Hephaestus regio and Dione regio, on the chart of 1897, is deducible in the drawings of December 9 and 14, 1877, more evident in that of December 21, 1877, and striking in those of July 5 and 30, 1895. The dark opening in it, marked *h* in the drawing of December 21, 1877, and visible again in that of July 30, 1895, which latter sketch Schiaparelli considered the best of all, is the Paris regio of the chart and appears in Fig. 4 lettered as *a*. The other dark indentation toward the limb to the left in the drawing of July 30, 1895, is the *b* of Fig. 4. Of these two dark points upon the limb I took position angles with the micrometer during June and July 1903, which speaks for the visibility of the markings. Indeed the difficulty of the micrometric measures came not so much from the markings as from the uncertainty of tangential determination near the cusp of the dichotomized disk. The position measures were as follows:

MARKING *b*.

G. M. T.	No. of Meas.	Mean P. A.	θ¶	Angle from cusp.
June 17, 12^h 11^m—24^m,	3	132°.9	103°.5	29°.4
23, 12 11	1	125 .0‖		
26, 12 12 —22	3	132 .5	106 .6	25 .9
30, 11 58, 12^h 9^m	3	134 .0	107 .9	26 .1
				Mean 27°.1

* Schiaparelli's Papers, 1878.

† Rendiconti del R. Ist. Lomb., Serie II, Vol. XXVIII, 1895.

‡ Acad. Roy. de Belgique Bulletins, Serie 3, Tome XXX, 1895.

¶ The angle which the line joining the cusps, or extremities of the illuminated portion, makes with the meridian.

‖ Taken parallel to line, not tangentially to limb.

Fig. 1.
March 22, $13^h\ 55^m$, G. M. T., $\lambda = 30°$

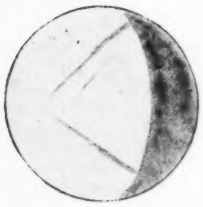


Fig. 2.
April 14, $7^h\ 8^m$, G. M. T., $\lambda = 48°$

Fig. 3.
April 14, $12^h\ 52^m$, G. M. T., $\lambda = 48°$

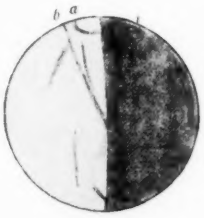


Fig. 4.
June 23, $12^h\ 5^m$, G. M. T., $\lambda = 81°$

EXPLANATION OF DRAWINGS.

Fig. 1 shows the collar at the south cusp, the two spots close to it, Astoreth and Ashera, and the long streaks, Anchises regio and Hero regio.

Figs. 2 and 3 show Anchises regio and Hero regio after the lapse of nearly six hours. It will be seen that they are unchanged in place; that is, that the rotation has no perceptible effect in that time.

Fig. 4 shows the aspect of the disk at about the date of dichotomy.

MARKING *a*, TIP OF PARIS REGIO ON LIMB.

	G. M. T.		No. of Meas.	Mean P. A.	θ	Angle from cusp.
July	1, 12^h	2^m—10^m,	3	130°.6	108°.2	22°.4
	2, 12	4 —17	4	127 .7	108 .4	19 .3
	8, 11	54	1	130 .8	110 .1	20 .7
	11, 12	30	1	129 .3	110 .8	18 .5
					Mean	20°.2
	18, 11	32 —44	2	132 .4	112 .3	20 .1
	21, 12	38	1	131 .8	112 .9	18 .9
	24, 12	36	1	133 .1	113 .5	19 .6
	25, 12	3 —16	3	131 .4	113 .8	17 .6
					Mean	19°.05
			Mean of all			19 .6

a was measured when the longitude of the center of the disk, λ, was from 79° to 86°; *b*, when it lay between 86° and 102°. At these central longitudes Hero regio is not well seen. On the other hand, when the longitudes of the center lay between 28° and 34°, it was the most evident marking on the disk in 1903, and was conspicuous up to $\lambda = 48°$. Similarly in 1901 it was the most salient marking at $\lambda = 23°$ to 33°. It appears from these instances that a marking is best seen as it passes under the observer's eye.

We may not improperly inquire into the cause of such discriminated showing and when we do so we are led at once to the perception that an atmosphere such as we know Venus to possess should produce just this effect. That the markings are due to cloud forms seems improbable, even in the case of the spoke-like streaks, and quite out of the question with regard to the collar and spots. For their permanency would negative it. The high albedo of the disk is, I am well aware, a difficulty which must be accounted for, but it seems possible to do so by the idea of a bright atmospheric veil as well as by a cloud canopy.

In conclusion it appears necessary, in view of the widespread and persistent misunderstanding of what the markings are, to assert again that they are in no sense canaliform. They bear no resemblance whatever to the "canals" of Mars. They are faint streaks or spots which have nothing about them of the remarkable regularity of the Martian "canals" and oases. They are not of even width, are not dark and sharp cut and do not form a system of interlacing lines. Nor are they ever double. Effects in the drawings which might be so taken differ entirely in look from gemination. Arguments applied to the one set are quite inapplicable to the other. Furthermore, they are of a much higher order of difficulty. Unless the conditions of visibility are such as to

show an observer the "canals" of Mars with ease and certainty it were useless to attempt this much harder planet.—From *Lowell Observatory*, Bulletin No. 6.

January 1, 1904.

METEOR OF SEPTEMBER 15, 1902.

E. L. MOSELEY.

For Popular Astronomy.

September 15, 1902, a meteor passed northward over Ohio, Ontario, and Michigan, so remarkable in several ways as to deserve more notice than it received from the newspapers at the time.

Where Seen.

As it passed before daybreak few persons were up early enough to see it, and it was a long time before I succeeded in learning of any observers outside of Ohio, acquaintances in other states of whom I enquired replying that they were unable to learn of anyone who saw it. Meteors of less brilliance, observed by my pupils or myself, I had made some effort to trace before, but had not followed them very far; one I concluded had burned out within 25 miles of Sandusky. According to a boy who was up early to carry papers, the meteor of Sept. 15th fell into Sandusky Bay about a quarter of a mile from him and he heard the splash. A man five miles east of the city said it was about 75 feet above the ground when it passed near him. An observer in Cleveland thought it fell into Lake Erie about five miles north of the city. Near Meadville, Pennsylvania, some workmen "saw it fall in the woods" and a Pittsburgh paper undertook to give its weight. By extensive correspondence and the insertion of letters of inquiry in many papers I have learned that it was seen throughout northern Ohio from Defiance to Ashtabula, in southern Ohio in Pike, Perry, Morgan and Washington counties, in western Pennsylvania at Erie, Edinborough and Meadville, in New York at Westfield, in Ontario at many places between Lake Erie and Lake Huron, also at Drayton and Arthur east of Lake Huron, in Michigan at Detroit, Port Huron, Ann Arbor, Lansing, and a number of other places in that part of the state, also in Osceola county about 240 miles west of Arthur, Ontario. So far my efforts to learn of observers in West Virginia or in Michigan north of Saginaw Bay have been unavailing. This, however, does not indicate that the meteor fell into Saginaw Bay, as observers

south of the bay thought, or into the southern part of Lake Huron as observers south of the lake thought. The weather map issued that morning shows a cloudy sky at stations in the northern half of Michigan, also in a part of West Virginia, though over most of this portion of North America the sky was clear.

The Path.

The meteor entered the Earth's atmosphere probably over West Virginia or southwestern Pennsylvania, passed over Mentor, 22 miles east of Cleveland, and over Sarnia, Ontario, near Port Huron, Michigan. Above Mentor its elevation was about 75 or 80 miles, when between London and Detroit about 73 miles. There is no clear evidence of any zig-zag or irregular motion or any bursting of the meteor.

Appearance.

The meteor passed over eastern Ohio and southwestern Ontario at about 5:42 A. M. Washington time. According to most observers it continued visible between ten and thirty seconds. It was egg-shaped or pear-shaped with the large end in front. To many it appeared to have about half the diameter of the full Moon, but was much brighter, giving probably several times as much light as the full Moon. The color was like that of an arc light, white or with a slightly bluish or possibly purplish tinge.

Sounds.

At Waverly in southern Ohio a rumbling sound was heard, but correspondents in southeastern Ohio do not report any sound. At many places in northern Ohio sounds were heard, but not very loud. At Defiance, from which the meteor when nearest was 175 miles distant, four observers interviewed by Dr. C. E. Slocum heard "a hissing noise." An observer near Sandusky heard "a slight hissing noise about as loud as a bee." M. F. Roberts, directly under the meteor at Mentor, heard "a rushing sound" that attracted his wife's attention.

In Michigan E. J. Smith and W. Kearns at Detroit heard "a loud sizzling noise." Near Port Huron an observer reported by C. K. Dodge heard "a great crackling and hissing, supposing at first it was his stove."

In Ontario, Andrew Smale, of Union, compared the noise to "that of an electric car running." The noise was heard by a number of persons in and near London, Ontario. J. B. McMurphy says of the sounds: "first like the swish of a falling tree, then changing to a noise similar to the striking of a parlor match

on some hard surface with not quite sufficient force to ignite it but enough to make it snap. It was something like this—Bir-rup-bir-rup-bir-rup, then changing to a sound like distant cannon. There were three such sounds as those. All those sounds were as if they had been produced from an echo and reproduced several times, each time growing fainter."

The greater intensity of the sound in Canada than in Ohio I suppose was due to the fact that the meteor was then moving through air not so rare as where it first became visible. The sound seems to have been no more noticeable directly under the meteor than many miles either side of its path.

Duration and Extent of the Train.

The train was observed by many who were not up early enough to see the meteor. Geo. D. Berry near Marietta, Ohio, estimated that it remained visible between five and eight minutes, but all observers farther north who kept watch of it give a longer time, quite a number giving "fifteen minutes" or "twenty minutes" or "until daylight." C. K. Dodge, of Port Huron, who is doubtless correct, reports it visible there for more than half an hour. The Pontiac reporter of the Detroit Tribune says "for at least half an hour." J. B. McMurphy, of London, Ontario, assures me that there the train was still visible sometime after sunrise and about an hour and a half after the meteor passed.

As seen from Ypsilanti, Michigan, the train extended so far from south to north that Mrs. F. K. Owen looking out an east window was unable to see either end of it. As seen at Port Huron it extended quite to the horizon a little west of north.

Form and Color of the Train.

At first the train formed an even curve or, as seen from some places, nearly straight line, but in a few minutes it began to be sinuous and gradually became quite zig-zag, as described by a number of observers.

J. B. McMurphy writes from London: "The sparks were very numerous and about the color of ordinary fire sparks. Later they appeared gray like ashes." Others speak of the train as "white," "a light streak," "lead colored streak," "phosphorescent glow," "color of full Moon on a clear night;" Mrs. Owen, Ypsilanti, "a band of shining light, silvery white, brighter toward the north, faded toward the south;" D. C. Johnson, of Marblehead, Ohio: "Sparks appeared to turn to white ashes that stayed until the wind blew them away."

Sandusky, Ohio.

THE OBSERVATION OF VARIABLE STARS.

COL. E. E. MARKWICK, F. R. A. S.

The study of variable stars is becoming more and more important, as the causes to which the light variations are due lie deep in the domain of cosmical physics, and in fact form some of the leading phenomena in the universe of stars. Hence their observation is becoming more and more an important branch of astronomy. Formerly the subject was practically left untouched in the program of official observatories; and even now, although they are watched in a few public observatories, the bulk of the work is being done in private observatories or by amateurs without any observatory at all.

The whole subject is one eminently suited to amateurs, as with comparatively small optical means a great deal of work may be done. A star such as Algol or β Lyræ can *only* be observed with the naked eye, while many such as S Sagittæ can *only* be observed with a binocular. Exception, of course, is made in the case of the photometer, which, however, is such an elaborate instrument as to be unlikely to be in the hands of an amateur. The reason why the stars named can only be so observed is that the comparison stars required to be used lie outside the field of view of the more highly magnifying telescope.

Variable stars, for the purpose of the ordinary, as distinguished from the professional observer may be roughly divided into four principal classes:

1. Algol type. Examples: Algol, U Cephei.
2. Short period. Examples: T Monocerotis, S Sagittæ.
3. Long period. Examples: R Leonis, χ Cygni.
4. Irregular. Examples: R Coronæ, R Scuti.

In the first type the variation in light is, beyond all reasonable doubt, due to the periodical eclipse, by the companion, of the primary star of a double system, in which the latter is bright, while the companion is smaller, and, generally, comparatively obscure. The necessary condition is that the plane of the orbit of the two stars pass through, or nearly through, the observer. With varying conditions of relative size and brightness of the two bodies, eccentricity and inclination of orbit to line of sight, it is obvious that the amount of variation may differ largely in different cases; but the type remains the same, that is to say, the light remains normal for the greater part of the period, the light change being gone through in a comparatively short time. Thus

the "period" of Algol is about $2^d\ 20^h\ 49^m$, while according to Chandler the light oscillations occupy a little over 9^h.

The second type of star has variation generally continuous throughout the period, which latter is usually confined within a few days. The light change is probably due to some orbital cause, but is far more difficult to explain than the first type.

The third type consists of stars whose variation runs into months; in some cases the period is shorter than our year, in others longer. Perhaps, on a very rough average, the period may approximate to our year. The change of light is most probably gradual all through the period, although generally most rapid shortly before or after maximum. There may be practically "any amount" of variation, from say 5th or 6th magnitude down to absolute invisibility. It is curious that in a powerful telescope some of these stars, when at minimum, present the appearance of a small, dim, nebula. No complete satisfactory theory of the long period stars has yet been given. The light changes appear to originate in the star itself; they may be very distantly analogous to our sun-spot changes, which is about all that can be said.

The fourth type are sufficiently described as "irregular." The light may continue unchanged for weeks or months, and then sudden and well-marked fluctuations in light will occur.

And now as to the observation of variable stars. It is premised in the following remarks that the person for whose edification they are intended has a good general knowledge of astronomy, but has not taken up this particular subject before. And, firstly as to instrumental appliances: much can be done with the naked eye, while a good binocular is all that is required for stars from, say, 4th to 7th magnitude. Below this a telescope is required. A 3-inch refractor with an eyepiece of low power, giving a wide flat field, will enable the observer to follow nearly all the long period variables through the greater, certainly the most interesting, part of their changes. Some of the long period variables at minimum, however, require the very highest optical power, but the amateur perhaps will hardly follow them up so closely as this.

It should not be forgotten that the details of the system of Algol, that is, the relative dimensions of the two globes, their period, the particulars of the orbit, etc., have all been determined from observations made by the naked eye alone, without any instrumental aid. The visual are supported by the spectroscopic observations.

The binocular is of very great use in observations of variable stars, as, firstly, the field of view is sufficiently large to contain in many cases the necessary comparison stars, and, secondly, it is so very portable. Whenever a clear gap occurs in the sky one needs only to pop out into the garden, or even the street, and the instrument can be focussed in a few seconds on the object. Unlike the case of a telescope fixed in an observatory, the observer by shifting his position can often easily "dodge" such intervening objects as trees, buildings, chimneys, or the like. The dark, unilluminated sky of the country is, of course, the best for this work, as it is for all other branches of observational astronomy. In towns, nowadays, observation is very much hampered by the glare from numerous electric lights, as well as by smoke and haze.

It is well to select a few variables to commence with, and concentrate observations on them. One good series of determinations of a variable is worth far more than a large number of scattered sporadic observations of many stars. The following twelve stars are suggested as a commencement, the particulars thereof having been extracted from Chandler's third "Catalogue of Variable Stars," which is a sure guide for the northern, and to a considerable extent, for the southern hemisphere. For the latter, if required, the observer may consult with advantage a "Catalogue of Southern Variables," recently issued by Mr. A. W. Roberts, of South Africa. Both these catalogues have been published in the *Astronomical Journal*, and could probably be obtained from Cambridge, Mass., U. S. A.

WORKING LIST.

Star.	1900.0.		Variation.		Period.	Remarks.
	R. A.	Decl.	From	To		
	h m	° ′	mag.	mag.		
U Cephei	0 53.4	+ 81 20	7.1	9.2	$2^d\ 11^h\ 49.6^m$	Algol type.
o (Mira) Ceti	2 14.3	— 3 26	{1.7 | 5.0	8) | 9.5}	331.6^d	Long period.
β Persei, Algol	3 1.7	+ 40 34	2.3	3.5	$2^d\ 20^h\ 48.9^m$	
T Monocerotis	6 19.8	+ 7 8	6.1	7.8	27.01^d	Short period.
R Leonis	9 42.2	+ 11 53	6.0±	9.7±	$312.\ 8^d$	Long period.
R Coronæ	15 44.4	+ 28 28	5.8	13.0	—	Irregular.
Z Herculis	17 53.6	+ 15 9	7.1	8.0	$3^d\ 23^h\ 49.9^m$	Algol type.
R Scuti	18 42.1	— 5 49	{4.7 | 5.7	6.0) | 9.0}	—	Irregular.
β Lyræ	18 46.4	+ 33 15	3.4	4.5	$12^d\ 21^h\ 47.4^m$	{Short period | with 2 min.
χ Cygni	19 46.7	+ 32 40	{4.0 | 6.5	13.5	406.02^d	Long period.
S Sagittæ	19 51.5	+ 16 22	5.6	6.4	8.38^d	Short period.
μ Cephei	21 40.4	+ 58 19	4?	5?	—	Irregular.

N. B.—R Scuti is given as periodic in the Catalogues, but it may perhaps be better described as above.

The above list may be gradually extended as the observer gains experience. Variable stars are constantly being discovered, and the field is of immense extent; although it must be stated there have been many "false alarms" in the past.

If unacquainted with the vicinity of the stars he is going to observe, and his telescope is not provided with "circles," the student should get their position roughly from a star atlas, such as Proctor's. He should prepare a map of the vicinity from the atlas of the "D. M.;" or, as this is perhaps difficult of access to many, he should prepare a little map himself, taking the positions of all the stars contained within a radius of 4° or 5° from the variable, which are to be found in the "Revised Harvard Photometry" (Vol. XLIV., Part I., of *Annals of Harvard College Observatory*), or in the *Photometric Durchmusterung* (Vol. XLV. of the same Annals). For further telescopic work nothing better can be recommended than the "Atlas Stellarum Variabilium" of Father Hagen. The three works named are indispensable.

A uniform system of recording observations should be adopted, as the results can then be obtained with comparative ease. It is convenient to use an observing book of about foolscap size. Enter therein the stars on the working list in order of Right Ascension, taking three folios or so for each star. At the top of page give name and Chandler's number of the variable, its *R.* A. and Decl., with brief particulars of variation, length of period, etc., which can be obtained from Chandler's Catalogue, etc. The maps may well be kept on loose sheets, in a separate portfolio, as they can easily be tilted up at any angle to represent the aspect of an asterism at any time.

Each page of the observing book is to be ruled in vertical columns, to contain the following:

1. Date and observation in G. M. T.
2. State of sky, which may be indicated by the following notation:

1 = good, first rate.
2 = not so good; clouds about, or hazy, etc.
3 = very bad; much hindrance.
T = twilight.
M = moon.

3. Instrument used; thus, n. e. = naked eye, Bin. = binocular, T 28 = telescope, power 28, etc.
4. Light estimate.
5. Remarks.
6. Deduced brightness.

We now come to the crux of the whole matter—viz., the completion of column 4. The visual determination of the brightness of a variable star is, as a rule, almost entirely *differential*. That is, it is made by comparing its light with that of other stars in the vicinity, whose "magnitude" (or brightness) is laid down. Suppose we have two suitable comparison stars, *a* and *b*, whose magnitudes as given in the catalogue are 4.2 and 4.9 respectively, and that a variable lies somewhere between them as regards brilliancy. Then there are two ways of estimating the brightness of the variable. *First*, by estimating at what fraction of the whole light-interval between *a* and *b*, from either one or the other of the two stars, the variable lies. Suppose it was thought to be at one-quarter the interval from *a* towards *b* (and therefore by implication three-quarters from *b* to *a*). This works out thus:

a.	4.2 mag.	To 4.2	mag. of *a*
b.	4.9 "	Add 0.18,	as the var. is fainter than *a*.
Diff.	0.7	Result 4.38	mag., or brightness of the variable.
1 quarter	0.18		

Or we might say:

Diff. as before	0.7	From 4.9	mag. of *b*
3 quarters	0.52	Subtract 0.52,	as the var. is brighter than *b*.
		Result 4.38	as before.

A convenient method of recording this particular observation is

a (1) *V* (3) *b*,

which explains itself, *V* indicating the variable, which is placed *after* the brighter star, and *before* the fainter one.

The *second* method is by the use of "steps;" the observer may estimate how many steps or tenths of a magnitude the variable is fainter than one star (say *a*) and brighter than another (say *b*). Supposing the observation to be "2 steps fainter than *a*, and 3 steps brighter than *b*;" then assuming that the observer's "step" corresponds truly to 0.1 of a mag., this works out:

By first determination 4.4 mag.
By second " 4.6 "
Mean ... ... 4.5 " resultant brightness of the var.

The second may be in the same form, viz.:

a (2) *V* (3) *b*,

but it should be stated clearly in the record, if the fractional method or the step method is used. In either case look at each star separately with the center of the eye, or eyes, not by averted vision.

It is open to the observer to make more than two determinations of brightness if he wish, and the mean of all may be taken. It is obvious also that there will be instances where the variable is exactly equal in brightness to some one of the comparison stars.

In refined methods, it is sometimes the practice for the observer to determine separately the exact fraction of a magnitude to which his "step" corresponds.

Simple determinations of intrinsic brightness of a star without any comparisons are worth little or nothing.

After all these precise instructions, the observer will probably find at first that he makes discordant observations, and sometimes, if he hesitates too much, he will be unable to say whether one star is brighter or fainter than another. After a little practice, however, as in most other things, the light estimate can be made with very fair precision and rapidity.

There are two classes of error which may affect determinations of brightness. These are (1) "Position error," in virtue of which an observer is liable to estimate too highly that one of two stars which has the smallest altitude. (2) "Possible misidentification of comparison stars." It seems hardly necessary to go into either of these in an elementary article like this.

The column "deduced magnitude" can be completed at leisure from the catalogue magnitude of the comparison stars.

In discussing the observations, it seems indispensable to plot them on square ruled paper, the abscissa being the time, and the ordinate the brightness deduced from the observations and expressed in magnitudes. A "smooth" or most probable curve is then drawn among the dots representing the observations. From this, if it is complete through a period, the date of maximum and minimum can be read off by inspection, and the character of the variation noted. Short period and Algol types must be plotted according to "phase," *i. e.*, according to the interval elapsed since the next preceding maximum or minimum.

If two or more observers combine their observations, the correctness of the results is vastly enhanced. Such a method as is sketched out above is in vogue in the Var. Star Section of the British Astronomical Association, and a series of results of very great reliability have been the final outcome of the co-operation of less than a dozen workers.—From *Knowledge Diary and Scientific Handbook* for 1904.

ASTRONOMY IN THE HIGH SCHOOL. III.

MARY E. BYRD.

FOR POPULAR ASTRONOMY.

DIURNAL PATHS OF HEAVENLY BODIES.

Ancient peoples who lived much out of doors had a sense of companionship with the heavenly bodies that we of the present day know little of. Not every advance to the estate of high civilization has been net gain. We have magnificent electric lighting, but we have lost the stars. Sun, Moon, planets and stars have dropped out of modern life almost as completely as if they had been blotted from heaven. To win back a place for them in human interest is not an unworthy ambition. Let us, then, who are teachers of astronomy, set for one of our first lessons, that oldest of all astronomical observations, to follow the Sun's diurnal circle in the heavens.

Turning first to one of the simplest methods, we find little required in the way of equipment except note-books, dark glasses, and an unobstructed view of the sky. Students themselves will be interested in finding places where they can conveniently watch the Sun. Neither time-piece nor almanac is essential. Any time within the hour from half after eleven to half after twelve may be taken as noon by them. At that time they should estimate the Sun's distance from the zenith by comparing it with the whole arc of 90° between zenith and horizon. It is not an easy estimate to make, and as there may be an error of 10°, no greater refinement than 5° need be attempted. That is, if the Sun seems a little more than a third of the way from horizon to zenith, its altitude is to be called 35°, if a little less, 25°. Since, however, direct estimates of noon altitude are invariably too large, it is fair to allow our students to correct their observed values by subtracting 5°. In entering the record in the note-book, it is well to include not only the final altitude, but the steps that lead up to it, and also a short description of the place of observing, so that each one may stand in the same place in the evening and on other days when watching the Sun. The evening observation is far simpler. As the Sun gets low in the west it is only necessary to outline roughly in the note-book, the trees or buildings near which its path is likely to meet the horizon, and then mark, with the symbol of the Sun, the point where the body drops out of sight. Five or six times during the school year at intervals of three weeks or more, the Sun's path should be located in this sim-

ple way by fixing the points of southing and setting, and on one of the dates it is desirable to include two or three intermediate positions.

A fair allotment of time to different kinds of observations does not permit so much attention to be given to other diurnal paths as to that of the Sun, but some notion of the way by which the Moon crosses the sky should be obtained on two or three evenings, one chosen when its path runs high and another when it is comparatively near the horizon. If on the latter date, a large part of the semi-diurnal path is traversed in the afternoon and early evening, the following exercise may be assigned.

1. Locate the Moon four times at intervals of half an hour or more, being careful each time to stand in the same place.

2. Before taking the first observation, sketch a part of the horizon line, beginning with the object just under the Moon and passing some distance to the west.

3. Estimate the altitude of the Moon by comparing its distance above an object on the horizon with the height of the object above the ground. Thus, if this is a church spire (blackboard illustration) and this the position of the Moon, you will place the Moon on a line passing through the top of the spire, and three times the height of the spire from the ground.

4. Mark positions found by dots accompanied by the symbol for the Moon.

If on the night of this observation one of the bright planets is near the Moon, its path may be included with little additional effort. Stars also may be observed in a similar manner, but it is far easier to gain a comprehensive idea of their motion with regard to our horizon by taking account of entire constellations somewhat as follows:

1. Record the positions of three constellations in the east with reference to some prominent object nearly in line with one of them.

2. Locate, in like manner, three constellations in the west.

3. At the end of an hour, record again the position of each constellation, noting the direction and amount of its motion.

Besides definite, prescribed observations of diurnal paths, there should be many times from month to month when Moon, planet or star is watched for a few minutes till it moves away from some fixed reference line, like that connecting two tree tops.

Simple methods like those outlined above permit students to receive directions and report results at regular class exercises, while at the same time carrying on work quite independently at

their individual places of observation. When, however, more critical methods are employed, requiring instrumental aid, it is essential to have one fixed place for observing. Preferably this should be near the recitation room and on the ground. Here most of the work is to be done under the direction of the class-room teacher or laboratory instructor. Estimates give place to measures, times are recorded to the nearest minute and noon-time is restricted to a short interval before and after the instant of the Sun's meridian passage. To meet these more exacting demands, the minimum equipment should include a north and south line, altazimuth, celestial globe, clock, ephemeris, and almanac.

A common almanac gives the time of apparent noon within a minute. A common clock should be trustworthy within a fraction of a minute if regulated by the daily time signals sent everywhere by telegraph. The "American Ephemeris and Nautical Almanac" supplies data for checking the small almanac, as well as data needed for the planets. It is found in experience that the home-made altazimuth used on a fair meridian line gives results that compare very favorably with those obtained from more expensive appliances. The line itself requires, perhaps, more attention than the instrument. When the place chosen for observation is on the ground, this line should be located on a large flag-stone, levelled and set even with the surface of the ground, its foundation being a deep layer of sand so as to dimish the effects of the weather. A gnomon post set up at the south side of the stone, and carefully adjusted, casts at apparent noon a shadow which lies directly north and south on the stone. If, then, the edge of the shadow is marked on four or five days, the mean position of the different lines thus fixed ought to give a meridian line sufficiently accurate for all except time observations. Thus furnished forth with time, meridian line, and an instrument for measuring angles, students can obtain positions in diurnal paths by merely pointing at the body and reading off altitude and azimuth from the graduated circles. Now, as in the work of astronomers, reduction and discussion take an important place. All paths should be plotted on rectangular paper, and critical points, rising, southing, and setting, checked on the celestial globe. The globe is also helpful in supplementing observations, showing as it does the symmetry of diurnal motion on either side of the meridian and illustrating paths of heavenly bodies in widely differing latitudes.

Since many of us who teach astronomy were never trained in

laboratory methods, there is danger of assigning unreasonably laborious or even impossible tasks. The most elementary exercises are not so simple as they seem. They require more time and effort, there is more in them than appears, facts, that stand out very clearly if we conscientiously undertake to follow our own instructions.

Times are long in astronomy. The shortest diurnal paths are seldom traversed in less than nine hours. Beginners, like more experienced observers, must often content themselves with following in the heavens only a small part of the path in which they are interested.

SMITH COLLEGE OBSERVATORY,
NORTHAMPTON, Mass.

PLANET NOTES FOR APRIL.

H. C. WILSON.

Mercury will be visible as evening star during the latter half of the month, being at greatest elongation, east from the Sun 20° 12′ on the afternoon of Apr. 21. Mercury will be in conjunction with Mars on April 8 but both planets will then be too near the Sun to be seen with the unaided eye.

Venus is morning star, seen near the eastern horizon an hour before sunrise. She is on the farther side of her orbit from us and presents nearly the full phase, but her brilliancy is getting near its minimum, because of her great distance from the Earth. Venus is at aphelion or greatest distance from the Sun April 1. She will come into conjunction with Jupiter on the morning of April 23, at 4 o'clock, C. S. T., the two planets being only 30′ apart in declination at that time.

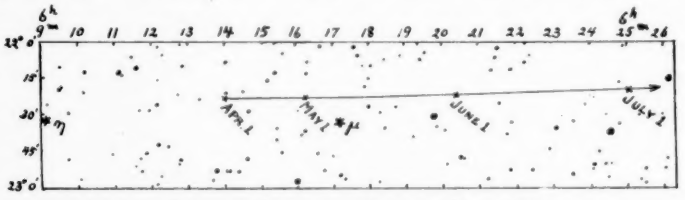
Mars is too close to the Sun to be observed easily, setting less than an hour after the Sun.

Jupiter is morning star, with Venus, now, but is not yet far enough out of the twilight for satisfactory observing.

Saturn may be observed toward the southeast in the morning hours, in the constellation Capricorn.

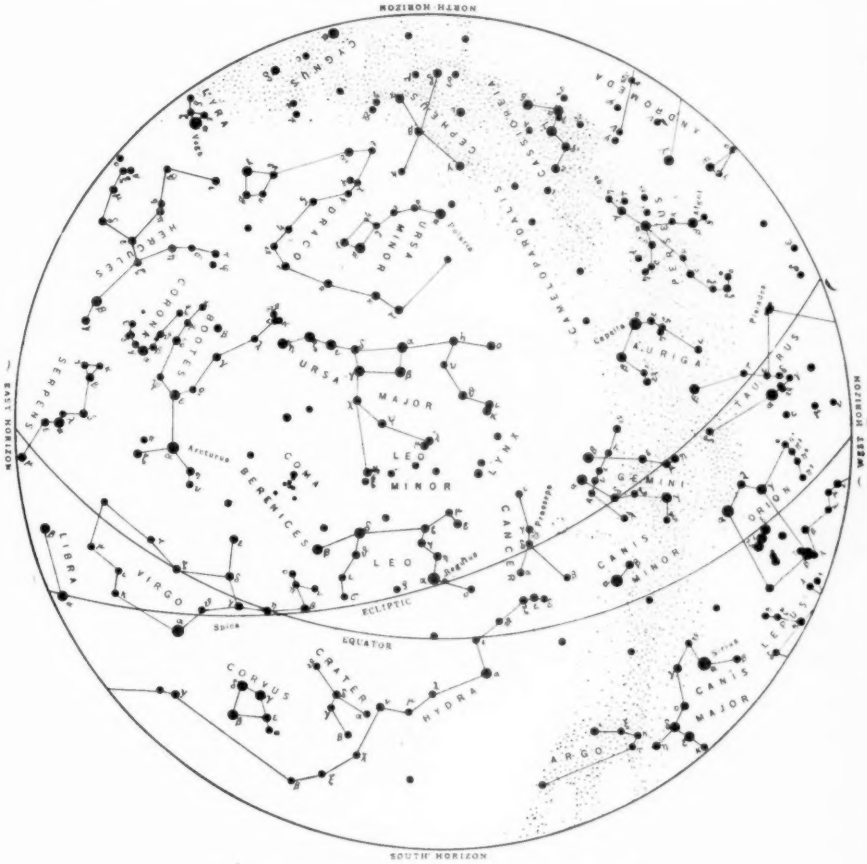
Uranus is at the stationary point of its path, at the west end of its course for the year, between the constellations Sagittarius and Scorpio. It may be observed with the aid of a telescope in the morning hours.

Neptune is the only planet in favorable position for evening observation. It may be found, with the aid of a telescope, in the constellation Gemini, between



APPARENT PATH OF NEPTUNE AMONG THE FAINT STARS NEAR μ GEMINORUM.

the stars η and μ. With the finder of a small telescope get the middle point between these two bright stars, then move the telescope to the south about one-



THE CONSTELLATIONS AT 9 P. M. APRIL 1, 1904.

third of the Moon's apparent diameter and sweep slowly toward the east Neptune ought either to be in the field of the larger telescope at first or to enter it immediately. The accompanying diagram may assist the observer. It gives the apparent path of Neptune for the next three months, showing all the faint neighboring stars whose places are given in the Bonn Durchmusterung. The planet will appear brighter than most of the stars shown along its path.

Ephemeris for Physical Observations of the Sun.

1904.	Greenwich Mean Noon. P.	D.	L.	1904.	Greenwich Mean Noon. P.	D.	L.
	° ′	° ′	° ′		° ′	° ′	° ′
Jan. 1	+ 2 22	− 3 8	203 49	July 4	− 1 14	+ 3 24	282 5
6	− 0 4	3 42	137 58	9	+ 1 2	3 55	215 54
11	2 29	4 14	72 7	14	3 19	4 25	149 44
16	4 53	4 45	6 17	19	5 31	4 53	83 34
21	7 12	5 13	300 27	24	7 41	5 18	17 25
26	9 27	5 38	234 37	29	9 47	5 42	311 17
31	11 36	6 1	166 47	Aug. 3	11 47	6 3	245 9
Feb. 5	13 38	6 21	101 57	8	13 42	6 22	179 2
10	15 33	6 38	37 7	13	15 31	6 38	112 57
15	17 20	6 52	331 17	18	17 13	6 51	46 52
20	18 58	7 3	265 27	23	18 47	7 2	340 48
25	20 28	7 10	199 36	28	20 15	7 9	274 44
Mar. 1	21 48	7 14	133 44	Sept. 2	21 34	7 14	208 40
6	22 59	7 15	67 51	7	22 44	7 15	142 38
11	24 0	7 12	1 57	12	23 45	7 13	76 37
16	24 51	7 6	296 3	17	24 38	7 8	10 38
21	25 31	6 57	230 9	22	25 20	7 0	304 38
26	26 1	6 45	164 14	27	25 53	6 49	238 38
31	26 21	6 30	98 16	Oct. 2	26 16	6 34	172 39
Apr. 5	26 29	6 12	32 16	7	26 27	6 17	106 41
10	26 27	5 51	326 17	12	26 29	5 57	40 44
15	26 14	5 27	260 17	17	26 19	5 34	334 47
20	25 49	5 2	194 15	22	25 57	5 9	268 50
25	25 14	4 34	128 12	27	25 24	4 41	202 54
30	24 27	4 4	62 8	Nov. 1	24 39	4 11	136 58
May 5	23 30	3 33	356 2	6	23 42	3 39	71 2
10	22 22	3 0	289 55	11	22 33	3 6	5 7
15	21 4	2 27	223 48	16	21 12	2 30	299 11
20	19 36	1 52	157 39	21	19 41	1 54	233 16
25	17 58	1 17	91 29	26	17 58	1 16	167 22
30	16 11	0 41	25 19	Dec. 1	16 6	+ 0 38	101 29
June 4	14 18	− 0 4	319 9	6	14 4	0 0	35 36
9	12 18	+ 0 32	252 59	11	11 56	− 0 38	329 43
14	10 11	1 8	186 48	16	9 41	1 16	263 50
19	8 2	1 43	120 37	21	7 19	1 54	197 58
24	5 48	2 18	55 26	26	4 55	2 31	132 7
29	− 3 31	+ 2 51	348 15	31	+ 2 39	− 3 6	66 16

The position-angle of the Sun's axis, P, is the position-angle of the N. end of the axis from the N. point of the Sun, read in the direction N., E., S., W. In computing D (the heliographic latitude of the center of the Sun's disk), the inclination of the Sun's axis to the ecliptic has been assumed to be 82° 45′, and the longitude of the ascending node to be 74° 25′. In computing L (the heliographic longitude of the center of the Sun's disk), the Sun's period of rotation has been assumed to be 25.38 days, and the meridian which passed through the ascending node at the epoch 1854.0 has been taken as the zero meridian. (From *The Companion to The Observatory*, 1904).

The Moon.

1904	Phases.	Rises. (Central Standard Time at Northfield. Local Time 18m less.) h m	Sets. h m
April 7	Last Quarter	1 18 A. M.	11 08 A. M.
15	New Moon	5 33 "	6 54 P. M.
22-23	First Quarter	10 50 "	1 33 A. M.
29-30	Full Moon	7 08 P. M.	5 48 "

Occultations Visible at Washington.

Date. 1904.		Star's Name.	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle from N pt. °	Duration. h m
Apr.	1	κ Virginis	4.3	7 24	54	7 55	345	0 31
	1	2 Libræ	6.3	13 13	146	14 20	259	1 07
	1	B.A.C. 4772	6.6	13 47	110	15 07	292	1 20
	2	σ^2 Libræ	6.3	15 02	133	16 16	259	1 14
	8	τ^2 Capricorni	5.3	14 06	79	15 15	268	1 9
	10	B.A.C. 7774	6.2	16 10	77	17 23	252	1 13
	21	λ Geminorum	3.6	10 30	132	11 18	251	0 48
	30	η Libræ	5.5	8 48	78	9 45	318	0 57
	30	θ Libræ	4.3	15 0	169	15 30	213	0 30

COMET AND ASTEROID NOTES.

New Asteroids.—The following have been added to the list of new planets since our last note:

	Discovered by	at	Local M. T. h m	R. A. ° ′	Decl. ° ′	Mag.
1904 MY	Dugan	Heidelberg	Jan. 10 6 51.4	2 3.7	+ 12 21	12.5
MZ	Dugan	"	10 6 51.4	2 17.1	15 8	10.5
NA	Dugan	"	10 10 30.5	4 48.2	21 57	11.3
NB	Dugan	"	10 10 30.5	5 0.5	22 54	11.2
NC	Wolf	"	10 14 3.5	8 1.5	+ 20 11	12.3

Asteroid Hertha (135) Variable.—A telegram has been received at the Harvard College Observatory from Professor Kreutz at Kiel Observatory stating that Palisa finds that the light of the planet Hertha is variable, with a range of half a magnitude, and a short period.

EPHEMERIS.

G. M. T. d	R. A. h m s	Decl. ° ′	Light.
1904 Feb. 21.5	9 36 52	+ 15 29	1.00
25.5	9 33 4	15 44	
29.5	9 29 28	15 58	
" Mar. 4.5	9 26 8	+ 16 11	0.95

Astronomical Bulletin, No. 147.

HARVARD COLLEGE OBSERVATORY, Cambridge, Mass.

Feb. 20, 1904.

VARIABLE STARS.

New Variable 1.1904 Persei.—Professor W. Ceraski of Moscow announces in *A. N.* 3924, the first new variable star of the year. It was discovered by Mme. L. Ceraski on 10 photographs taken at Moscow, and varies between the 9th and 12th magnitudes. Its position is

1855	R. A. $2^h\ 18^m\ 50^s.0$	Decl. $+ 50^\circ\ 37'.7$
1900	$2\ 21\ 50.5$	$+ 50\ 50.0$

The period is not yet determined.

Ephemeris for Physical Observations of the Sun.

1904.	Greenwich Mean Noon. P.	D.	L.	1904.	Greenwich Mean Noon. P.	D.	L.
	° ′	° ′	° ′		° ′	° ′	° ′
Jan. 1	+ 2 22	− 3 8	203 49	July 4	− 1 14	+ 3 24	282 5
6	− 0 4	3 42	137 58	9	+ 1 2	3 55	215 54
11	2 29	4 14	72 7	14	3 19	4 25	149 44
16	4 53	4 45	6 17	19	5 31	4 53	83 34
21	7 12	5 13	300 27	24	7 41	5 18	17 25
26	9 27	5 38	234 37	29	9 47	5 42	311 17
31	11 36	6 1	166 47	Aug. 3	11 47	6 3	245 9
Feb. 5	13 38	6 21	101 57	8	13 42	6 22	179 2
10	15 33	6 38	37 7	13	15 31	6 38	112 57
15	17 20	6 52	331 17	18	17 13	6 51	46 52
20	18 58	7 3	265 27	23	18 47	7 2	340 48
25	20 28	7 10	199 36	28	20 15	7 9	274 44
Mar. 1	21 48	7 14	133 44	Sept. 2	21 34	7 14	208 40
6	22 59	7 15	67 51	7	22 44	7 15	142 38
11	24 0	7 12	1 57	12	23 45	7 13	76 37
16	24 51	7 6	296 3	17	24 38	7 8	10 38
21	25 31	6 57	230 9	22	25 20	7 0	304 38
26	26 1	6 45	164 14	27	25 53	6 49	238 38
31	26 21	6 30	98 16	Oct. 2	26 16	6 34	172 39
Apr. 5	26 29	6 12	32 16	7	26 27	6 17	106 41
10	26 27	5 51	326 17	12	26 29	5 57	40 44
15	26 14	5 27	260 17	17	26 19	5 34	334 47
20	25 49	5 2	194 15	22	25 57	5 9	268 50
25	25 14	4 34	128 12	27	25 24	4 41	202 54
30	24 27	4 4	62 8	Nov. 1	24 39	4 11	136 58
May 5	23 30	3 33	356 2	6	23 42	3 39	71 2
10	22 22	3 0	289 55	11	22 33	3 6	5 7
15	21 4	2 27	223 48	16	21 12	2 30	299 11
20	19 36	1 52	157 39	21	19 41	1 54	233 16
25	17 58	1 17	91 29	26	17 58	1 16	167 22
30	16 11	0 41	25 19	Dec. 1	16 6	+ 0 38	101 29
June 4	14 18	− 0 4	319 9	6	14 4	0 0	35 36
9	12 18	+ 0 32	252 59	11	11 56	− 0 38	329 43
14	10 11	1 8	186 48	16	9 41	1 16	263 50
19	8 2	1 43	120 37	21	7 19	1 54	197 58
24	5 48	2 18	55 26	26	4 55	2 31	132 7
29	− 3 31	+ 2 51	348 15	31	+ 2 39	− 3 6	66 16

The position-angle of the Sun's axis, P, is the position-angle of the N. end of the axis from the N. point of the Sun, read in the direction N., E., S., W. In computing D (the heliographic latitude of the center of the Sun's disk), the inclination of the Sun's axis to the ecliptic has been assumed to be 82° 45′, and the longitude of the ascending node to be 74° 25′. In computing L (the heliographic longitude of the center of the Sun's disk), the Sun's period of rotation has been assumed to be 25.38 days, and the meridian which passed through the ascending node at the epoch 1854.0 has been taken as the zero meridian. (From *The Companion to The Observatory*, 1904).

The Moon.

1904	Phases.	Rises. (Central Standard Time at Northfield. Local Time 18m less.) h m	Sets. h m
April 7	Last Quarter	1 18 A. M.	11 08 A. M.
15	New Moon	5 33 "	6 54 P. M.
22-23	First Quarter	10 50 "	1 33 A. M.
29-30	Full Moon	7 08 P. M.	5 48 "

Occultations Visible at Washington.

Date. 1904.	Star's Name.	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle from N pt. °	Duration. h m
Apr. 1	κ Virginis	4.3	7 24	54	7 55	345	0 31
1	2 Libræ	6.3	13 13	146	14 20	259	1 07
1	B.A.C. 4772	6.6	13 47	110	15 07	292	1 20
2	o^2 Libræ	6.3	15 02	133	16 16	259	1 14
8	τ^2 Capricorni	5.3	14 06	79	15 15	268	1 9
10	B.A.C. 7774	6.2	16 10	77	17 23	252	1 13
21	λ Geminorum	3.6	10 30	132	11 18	251	0 48
30	η Libræ	5.5	8 48	78	9 45	318	0 57
30	θ Libræ	4.3	15 0	169	15 30	213	0 30

COMET AND ASTEROID NOTES.

New Asteroids.—The following have been added to the list of new planets since our last note:

	Discovered by	at	Local M. T. h m	R. A. ° ′	Decl. ° ′	Mag.
1904 MY	Dugan	Heidelberg	Jan. 10 6 51.4	2 3.7	+ 12 21	12.5
MZ	Dugan	"	10 6 51.4	2 17.1	15 8	10.5
NA	Dugan	"	10 10 30.5	4 48.2	21 57	11.3
NB	Dugan	"	10 10 30.5	5 0.5	22 54	11.2
NC	Wolf	"	10 14 3.5	8 1.5	+ 20 11	12.3

Asteroid Hertha (135) Variable.—A telegram has been received at the Harvard College Observatory from Professor Kreutz at Kiel Observatory stating that Palisa finds that the light of the planet Hertha is variable, with a range of half a magnitude, and a short period.

EPHEMERIS.

G. M. T. d	R. A. h m s	Decl. ° ′	Light.
1904 Feb. 21.5	9 36 52	+ 15 29	1.00
25.5	9 33 4	15 44	
29.5	9 29 28	15 58	
" Mar. 4.5	9 26 8	+ 16 11	0.95

Astronomical Bulletin, No. 147.

HARVARD COLLEGE OBSERVATORY, Cambridge, Mass.

Feb. 20, 1904.

VARIABLE STARS.

New Variable 1.1904 Persei.—Professor W. Ceraski of Moscow announces in *A. N.* 3924, the first new variable star of the year. It was discovered by Mme. L. Ceraski on 10 photographs taken at Moscow, and varies between the 9th and 12th magnitudes. Its position is

1855	R. A. 2^h 18^m $50^s.0$	Decl. + 50°	37′.7
1900	2 21 50 .5	+ 50	50 .0

The period is not yet determined.

Minima of Variable Stars of the Algol Type.

[Greenwich Mean Time beginning with noon. The hours from 12 to 24 are those which occur in the night in the United States. To obtain Eastern Standard time subtract 5 hours; for Central Standard time subtract 6 hours, etc.]

U Cephei.

	d	h
Apr	2	0
	4	12
	7	0
	9	12
	11	23
	14	11
	16	23
	19	11
	21	23
	24	11
	26	22
	29	10

Z Persei

	d	h
Apr.	1	3
	4	4
	7	5
	10	7
	13	8
	16	9
	19	11
	22	12
	25	14
	28	15

Algol.

	d	h
Apr.	1	17
	4	14
	7	11
	10	7
	13	4
	16	1
	18	22
	21	19
	24	15
	27	12
	30	9

R Canis Maj.

	d	h
Apr.	1	10
	2	13
	3	16
	4	20
	5	23
	7	2
	8	5
	9	9
	10	12
	11	15
	12	18
	13	22
	15	1
	16	4
	17	7
	18	11
	19	14

R Canis Maj.

	d	h
Apr.	20	17
	21	21
	23	0
	24	3
	25	6
	26	10
	27	13
	28	16
	29	19
	30	23

RR Puppis

	d	h
Apr.	6	23
	13	9
	19	19
	26	6

V Puppis.

	d	h
Apr.	2	3
	3	14
	5	1
	6	12
	8	0
	9	10
	10	21
	12	8
	13	19
	15	5
	16	16
	18	3
	19	14
	21	1
	22	12
	23	23
	25	10
	26	21
	28	8
	29	19

S Cancri

	d	h
Apr.	3	8
	12	19
	22	7

S Velorum.

	d	h
Apr.	4	18
	10	16
	16	15
	22	13
	28	12

W. Urs. Maj.

Period $4^h\ 0^m.2$

Apr. 1-26 6^h

27-30 7^h

RR Velorum.

	d	h
Apr.	2	16
	4	13
	6	9
	8	6
	10	2
	11	23
	13	19
	15	16
	17	12
	19	9
	21	6
	23	2
	24	22
	26	19
	28	16
	30	12

Z Draconis.

	d	h
Apr.	1	10
	2	19
	4	3
	5	12
	6	20
	8	5
	9	13
	10	22
	12	7
	13	15
	14	24
	16	8
	17	17
	19	1
	20	10
	21	19
	23	3
	24	12
	25	20
	27	5
	28	14
	29	22

δ Librae.

	d	h
Apr.	2	4
	4	12
	6	20
	9	3
	11	11
	13	19
	16	3
	18	11
	20	19
	23	3
	25	10
	27	18
	30	2

U Coronae.

	d	h
Apr.	4	8
	7	19
	11	6
	14	17
	18	4
	21	14
	25	1
	28	12

R Aræ.

	d	h
Apr.	3	2
	7	13
	11	23
	16	9
	20	19
	25	5
	29	16

U Ophiuchi.

	d	h
Apr.	1	11
	2	7
	3	3
	3	23
	4	19
	5	16
	6	12
	7	8
	8	4
	9	0
	9	20
	10	16
	11	12
	12	9
	13	5
	14	1
	14	21
	15	17
	16	13
	17	9
	18	5
	19	2
	19	22
	20	18
	21	14
	22	10
	23	6
	24	2
	24	22
	25	19
	26	15
	27	11
	28	7
	29	3
	29	23
	30	19

Z Herculis.

	d	h
Apr.	1	1
	2	22
	5	1
	6	22
	9	1
	10	22
	13	0
	14	21
	17	0
	18	21
	21	0
	22	21
	25	0
	26	21
	29	0
	30	21

RS Sagittarii.

	d	h
Apr.	2	23
	5	9
	7	19
	10	5
	12	15
	15	1
	17	11
	19	21
	22	7
	24	17
	27	3
	29	13

RX Herculis.

	d	h
Apr.	1	18
	2	15
	3	12
	4	10
	5	7
	6	4
	7	2
	7	23
	8	20
	9	18
	10	15
	11	12
	12	10
	13	7
	14	4
	15	2
	15	23
	16	20
	17	18
	18	15
	19	12
	20	10

Minima of Variable Stars of the Algol Type.—Continued.

RX Herculis.

	d	h
Apr.	21	7
	22	4
	23	2
	23	23
	24	21
	25	18
	26	15
	27	13
	28	10
	29	7
	30	5

RV Lyræ.

	d	h
Apr.	1	7
	4	22
	8	12
	12	2
	15	17
	19	7
	22	22
	26	12
	30	2

U Sagittæ.

	d	h
Apr.	1	15
	5	0
	8	9
	11	19
	15	4
	18	13
	21	22
	25	7
	28	16

SY Cygni.

	d	h
Apr.	1	16
	7	16
	13	16
	19	17
	25	17

SW Cygni.

	d	h
Apr.	4	1
	8	15
	13	5
	17	18
	22	8
	26	22

UW Cygni.

	d	h
Apr.	3	1
	6	12
	9	22
	13	9
	16	20
	20	7
	23	18
	27	4
	30	15

W Delphini.

	d	h
Apr.	2	9
	7	4
	12	0
	16	19
	21	14
	26	10

VV Cygni.

	d	h
Apr.	2	10
	3	21
	5	9
	6	20

VV Cygni.

	d	h
Apr.	8	8
	9	19
	11	6
	12	18
	14	5
	15	17
	17	4
	18	16
	20	3
	21	15
	23	2
	24	14
	26	1
	27	12
	29	0
	30	11

VW Cygni.

	d	h
Apr.	5	7
	13	17
	22	3
	30	14

Y Cygni.

	d	h
Apr.	1	18
	3	4
	4	18
	6	4
	7	18
	9	3
	10	18
	12	3
	13	18
	15	3
	16	18
	18	3
	19	18
	21	3
	22	18
	24	3
	25	18
	27	3
	28	18
	30	3

UZ Cygni.

	d	h
Apr.	17	21

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$. The minimum occurs $1^h\ 40^m$ before the maximum.

	d	h		d	h		d	h		d	h
Apr.	1	14	Apr.	9	15	Apr.	17	16	Apr.	25	17
	2	14		10	15		18	16		26	17
	3	14		11	15		19	17		27	18
	4	15		12	16		20	17		28	18
	5	15		13	16		21	17		29	18
	6	15		14	16		22	17		30	18
	7	15		15	16		23	17			
	8	15		16	16		24	17			

Maxima of UY Cygni.

Period $13^h\ 27^m\ 27^s.6$. The minimum occurs $1^h\ 53^m$ before the maximum.

	d	h		d	h		d	h		d	h
Apr.	1	3	Apr.	9	0	Apr.	16	20	Apr.	24	16
	2	6		10	3		17	23		25	19
	3	9		11	5		19	2		26	22
	4	12		12	8		20	5		28	1
	5	15		13	11		21	8		29	4
	6	18		14	14		22	11		30	7
	7	21		15	17		23	14			

Maxima of RZ Lyræ.

Period $12^h\ 16^m\ 15^s.0$.

	d	h		d	h		d	h		d	h
Apr.	1	19	Apr.	9	12	Apr.	18	17	Apr.	26	21
	2	20		10	13		19	18		27	22
	3	21		11	13		20	18		28	22
	4	21		12	14		21	19		29	23
	5	22		13	14		22	19		30	23
	6	22		14	15		23	20			
	7	23		16	16		24	20			
	8	12		17	16		25	21			

Variable Stars of Short Period not of the Algol Type.

	Minimum.		Maximum.	
	d	h	d	h
T Vulpeculae	Apr. 1	6	Apr. 2	15
V Velorum	1	8	2	7
δ Cephei	2	3	3	12
S Crucis	2	3	3	15
V Centauri	2	8	3	19
T Crucis	2	15	4	16
X Sagittarii	2	16	5	13
U Aquilae	2	21	5	1
SU Cygni	3	8	5	16
X Cygni	3	17	9	22
S Sagittæ	4	5	7	15
R Crucis	4	10	5	19
T Velorum	4	12	5	21
ζ Geminorum	4	14	9	14
Y Sagittarii	4	17	6	12
S Normae	4	17	9	3
η Aquilae	5	3	7	12
U Vulpeculae	5	5	7	8
RV Scorpii	5	13	6	23
V Velorum	5	17	6	16
T Vulpeculae	5	17	7	2
S. Triang. Austr.	5	19	7	21
W Geminorum	6	11	9	2
R Crucis	6	19	8	7
V Carinae	6	21	9	1
U Sagittarii	6	22	9	21
δ Cephei	7	0	8	9
β Lyræ	7	2	10	4
W Sagittarii	7	11	10	11
SU Cygni	7	4	8	12
V Centauri	7	20	9	7
κ Pavonis	8	20	12	15
T Velorum	9	3	10	12
S Muscae	9	12	12	23
X Sagittarii	9	16	12	13
Y Ophiuchi	9	16	15	21
U Aquilae	9	21	12	1
V Velorum	10	2	11	1
T Vulpeculae	10	3	11	12
R Crucis	10	6	11	15
T Crucis	10	9	12	10
Y Sagittarii	10	11	12	6
TX Cygni	10	18	15	21
SU Cygni	11	0	12	8
S Crucis	11	12	13	0
RV Scorpii	11	15	13	1
S Trianguli Austr.	12	3	14	17
η Aquilae	12	7	14	16
δ Cephei	12	9	13	18
S Sagittae	12	14	16	0
U Vulpeculae	13	4	15	7
V Centauri	13	8	14	19
β Lyrae	13	13	16	20
V Carinae	13	14	15	18
U Sagittarii	13	16	16	15
T Velorum	13	19	15	4
SU Cygni	13	20	15	5
W Sagittarii	14	2	17	2
W Geminorum	14	5	16	20
V Velorum	14	11	15	10
S Normae	14	11	18	21

	Minimum.		Maximum.	
	d	h	d	h
T Vulpeculae	Apr. 14	13	Apr. 15	22
ζ Geminorum	14	18	19	18
W Virginis	15	1	23	6
R Crucis	16	1	17	10
S Crucis	16	4	17	16
Y Sagittarii	16	6	18	1
X Sagittarii	16	17	19	14
U Aquilae	16	22	19	2
T Crucis	17	2	19	3
U Vulpeculae	17	8	20	11
RV Scorpii	17	16	19	2
δ Cephei	17	17	19	3
κ Pavonis	17	22	21	17
T Velorum	18	10	19	19
S Triang. Austr.	18	11	20	13
SU Cygni	18	17	20	1
V Centauri	18	20	20	7
V Velorum	18	20	19	19
T Vulpeculae	19	0	20	9
S Muscae	19	4	22	15
η Aquilae	19	11	21	20
β Lyrae	20	0	23	2
X Cygni	20	2	26	7
V Carinae	20	7	22	11
U Sagittarii	20	10	23	9
S Crucis	20	21	22	9
S Sagittae	21	0	24	10
W Sagittarii	21	16	24	16
R Crucis	21	21	23	6
W Geminorum	21	23	24	14
Y Sagittarii	22	0	23	19
δ Cephei	23	2	24	11
T Velorum	23	2	24	11
V Velorum	23	5	24	4
X Sagittarii	23	17	27	14
T Vulpeculae	23	10	24	19
RV Scorpii	23	18	25	4
T Monocerotis	23	20	31	18
T Crucis	23	21	25	22
U Aquilae	23	22	26	2
S Normae	24	5	28	15
V Centauri	24	8	25	19
S Triang. Austr.	24	18	26	20
ζ Geminorum	24	21	29	21
U Vulpeculae	25	7	27	10
TX Cygni	25	12	30	15
S Crucis	25	13	27	1
SU Cygni	26	9	27	18
β Lyrae	26	11	29	18
η Aquilae	26	15	29	0
Y Ophiuchi	26	19	33	0
V Carinae	26	23	29	3
κ Pavonis	27	0	30	19
U Sagittarii	27	4	30	3
V Velorum	27	14	28	13
T Velorum	27	17	29	2
R Crucis	27	17	29	2
Y Sagittarii	27	19	29	14
T Vulpeculae	27	21	29	6
δ Cephei	28	11	29	20
S Muscae	28	20	32	7

Variable Stars of Short Period not of the Algol Type.—Continued.

	Minimum.		Maximum.			Minimum.		Maximum.	
	d	h	d	h		d	h	d	h
W Sagittarii	Apr. 29	6	Apr. 32	6	V Centauri	Apr. 29	20	Apr. 31	7
S Sagittae	29	9	32	19	SU Cygni	30	5	31	13
W Geminorum	29	17	32	8	T Crucis	30	14	33	1
RV Scorpii	29	19	31	5					

Approximate Magnitudes of Variable Stars Feb. 10, 1904.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900.		Decl. 1900.		Magn.	Name.	R. A. 1900.		Decl. 1900.		Magn.
	h	m	°	′			h	m	°	′	
T Androm.	0	17.2	+ 26	26	11*i*	R Camel.	14	25.1	+ 84	17	12*d*
T Cassiop.	0	17.8	+ 55	14	8*i*	R Bootis	14	32.8	+ 27	10	10*i*
R Androm.	0	18.8	+ 38	1	6*i*	S Librae	15	15.6	— 20	2	11*d*
S Ceti	0	19.0	— 9	53	*f*	S Serpentis	15	17.0	+ 14	40	*i*
W Cassiop.	0	49.0	+ 58	1	*u*	S Coronae	15	17.3	+ 31	44	8*i*
S "	1	12.3	+ 72	5	12*d*	S Urs. Min.	15	33.4	+ 78	58	8
R Piscium	1	25.5	+ 2	22	13*d*	R Coronae	15	44.4	+ 28	28	6
R Trianguli	1	31.0	+ 33	50	10*d*	V "	15	45.9	+ 39	52	*u*
U Persei	1	52.9	+ 54	20	10*d*	R Serpentis	15	46.1	+ 15	26	*f*
R Arietis	2	10.4	+ 24	36	11*d*	R Herculis	16	1.7	+ 18	38	11*d*
o Ceti	2	14.3	— 3	26	4*i*	R Scorpii	16	11.7	— 22	42	*s*
S Persei	2	15.7	+ 58	8	10*d*	S "	16	11.7	— 22	39	*s*
R Ceti	2	20.9	— 0	38	12	U Herculis	16	21.4	+ 19	7	8*i*
U "	2	28.9	— 13	35	13*f*	R Ursae Min.	16	31.3	+ 72	28	*u*
R Persei	3	23.7	+ 35	20	*u*	W Herculis	16	31.7	+ 37	32	8
R Tauri	4	22.8	+ 9	56	8	R Draconis	16	32.4	+ 66	58	10*i*
S "	4	23.7	+ 9	44	11*i*	S Herculis	16	47.4	+ 15	7	10*d*
R Aurigæ	5	9.2	+ 53	28	9*i*	R Ophiuchi	17	2.0	— 15	58	*f*
U Orionis	5	49.9	+ 20	10	10*i*	T Herculis	18	5.3	+ 31	0	*f*
R Lyncis	6	53.0	+ 55	28	12*d*	R Scuti	18	42.2	— 5	49	*s*
R Gemin.	7	1.3	+ 22	52	12*d*	R Aquilae	19	1.6	+ 8	5	*s*
S Canis Min.	7	27.3	+ 8	32	8*i*	R Sagittarii	19	10.8	— 19	29	*s*
R Cancri	8	11.0	+ 12	2	10*d*	S "	19	13.6	— 19	12	*s*
V "	8	16.0	+ 17	36	9*i*	R Cygni	19	34.1	+ 49	58	11*d*
S Hydrae	8	48.4	+ 3	27	8*i*	RT "	19	40.8	+ 48	32	*f*
T "	8	50.8	— 8	46	8*i*	X "	19	46.7	+ 32	40	9*d*
R Leo. Min.	9	39.6	+ 34	58	10*d*	S Cygni	20	3.4	+ 57	42	*f*
R Leonis	9	42.2	+ 11	54	10*d*	RS "	20	9.8	+ 38	28	8*d*
R Urs. Maj.	10	37.6	+ 69	18	13*d*	R Delphini	20	10.1	+ 8	47	*s*
R Comae	11	59.1	+ 19	20	*f*	U Cygni	20	16.5	+ 47	35	8*i*
T Virginis	12	9.5	— 5	29	9*i*	V "	20	38.1	+ 47	47	11*i*
R Corvi	12	14.4	— 18	42	7*i*	T Aquarii	20	44.7	— 5	31	*s*
Y Virginis	12	28.7	— 3	52	10*i*	R Vulpec.	20	59.9	+ 23	26	*s*
T Urs. Maj.	12	31.8	+ 60	2	13*d*	T Cephei	21	8.2	+ 68	5	6*i*
R Virginis	12	33.4	+ 7	32	7*i*	S "	21	36.5	+ 78	10	8*d*
S Urs. Maj.	12	39.6	+ 61	38	12*d*	S Lacertae	22	24.6	+ 39	48	13*d*
U Virginis	12	46.0	+ 6	6	11*d*	R "	22	38.8	+ 41	51	12*f*
V "	13	22.6	— 2	39	10*d*	S Aquarii	22	51.8	— 20	53	*s*
R Hydrae	13	24.2	— 22	46	6*i*	R Pegasi	23	1.6	+ 10	0	12*d*
S Virginis	13	27.8	— 6	41	12*d*	S "	23	15.5	+ 8	22	8
R Can. Ven.	13	44.6	+ 40	2	11*i*	R Aquarii	23	38.6	— 15	50	6
S Bootis	14	19.5	+ 54	16	11*d*	R Cassiop.	23	53.3	+ 50	50	6*i*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

Derived from observations made at the Halsted, Vassar College and Harvard Observatories, and by Signor de Moraes Pereira, St. Michaels, Azores.

New Variable 2.1904 Tauri.—This is announced in *A. N.* 3925 by Professor Millosevich of Rome. It is not found in the BD. but is No. 1625 in the *Berlin A. G. Catalogue*, where its position for 1875 is given as

R. A. $4^h\ 56^m\ 39^s.51$, Decl. $+23°\ 28'\ 7''.5$

In the catalogue the magnitude is given as 9.3 but Professor Millosevich finds it on Jan. 17, 1904 to be 10.3, so that its variability is apparent.

New Variable 3.1904 Cancri.—Professor Wolf of Heidelberg announces in *A. N.* 3925, that a star standing between the three BD. stars $+20°.1992$, 1994 and 1997 was of the 12 mag. Jan. 10 and of the 14 mag. Jan. 11, 1904. Its position for 1855 is

R. A. $7^h\ 56^m.0$, Decl. $+20°\ 32'$.

Variable Star 63.1903 Lyræ.—Dr. Hartwig gives the following position of this star in *A. N.* 3921

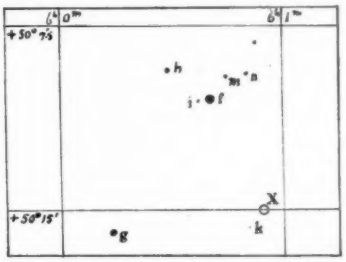
	α			δ		
1855	19^h	9^m	$7^s.51$	$+46°$	$43'$	$59''.0$
1900	19	10	24 .12	+46	48	36 .3

New Variables 64-85.1903 Aquila.—These are all in the region about γ Aquilæ and were found with the aid of the Stereo-Comparator, upon photographs taken with the Bruce cameras at Heidelberg, July 19.1901 and Sept. 24.1903. The following are their positions for 1900, and the photographic magnitudes on the two dates:

	R. A.			Decl.			Magnitude July 19.1901.	Magnitude Sept. 24.1903.
	h	m	s	°	′	″		
64.1903	19	27	48.8	+10	18	39	11.5	15
65 "		30	25.8	7	2	14	14	12.5
66 "		33	11.2	12	33	45	< 14	13
67 "		34	2.8	12	2	22	11	14.5
68 "		34	20.2	11	43	5	< 14	13
RV		35	56.7	9	41	57	13	10.5
69 "		36	21.6	7	11	3	14	11.5
70 "		38	6.2	13	20	7	12.0	14.5
71 "		40	21.5	8	12	12	11.0	< 15
72 "		41	47.0	10	32	24	< 15	13.5
73 "		41	56.0	10	13	6	< 15	14
74 "		42	22.6	7	23	4	13.5	11.5
75 "		42	30.2	12	14	19	11.5	< 15
76 "		42	49.4	9	41	57	< 15	12.0
77 "		43	39.8	11	16	33	10.0	12.0
78 "		44	34.8	12	7	7	11.0	13
79 "		46	0.2	12	33	58	14	11.5
80 "		46	15.3	12	58	0	11	< 14
81 "		48	42.4	9	6	37	12	14
82 "		48	59.4	10	44	5	12	13
83 "		49	6.3	9	24	1	11	13
84 "		49	24.8	7	21	1	12.5	11.5
85 "	19	49	32.7	+ 7	44	40	13	< 14

The variable RT Aquilæ (R. A. $= 19^h\ 43^m\ 17^s$, Decl. $= +11°\ 29'$, 1900.0) was not visible upon these plates. It seems remarkable that so many variables should be found within so small an area of the sky.

The Light Change of X Aurigæ.—In *A. N.* 3925 Dr. K. Graff of the Hamburg Observatory gives the results of a determination of the light-curve of this variable, which was discovered by Anderson in 1900 and was first designated

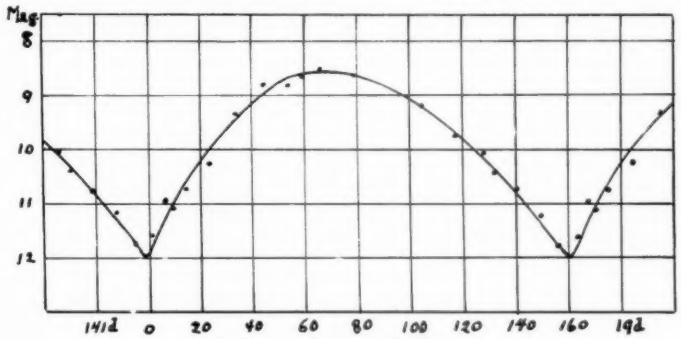


COMPARISON STARS NEAR X AURIGÆ.

as 8.1900 Aurigæ. The observations employed extend from Feb. 26, 1902 to Sept. 19, 1903. He finds the period to be 161 days, the minimum being found by the elements

$$\text{Min.} = 1902 \text{ Oct. } 6 + 161 \text{ E}$$
$$= \text{J. D. } 2416029 + 161 \text{ E}$$

The form of the light curve is shown in the accompanying diagram.



THE LIGHT CURVE OF X AURIGÆ.

Dr. Graff gives the following list of ten comparison stars with their approximate positions for 1855:

		R. A.			Decl.		Mag.
		h	m	s	°	′	
a	BD. + 49°1464	6	1	6	+ 49	58.2	8.65
b	BD. + 50°1275	5	58	41	50	10.5	8.45
c	BD. + 50°1281	6	1	21	50	37.9	8.70
f		6	0	39	50	10.8	9.80
g		6	0	14	50	16.0	10.25
h		6	0	29	50	9.3	10.50
i		6	0	37	50	10.9	11.2
k		6	0	52	50	16.3	12.4
m		6	0	47	50	9.4	11.1
n		6	0	50	+ 50	9 3	11.0

GENERAL NOTES.

Our readers will surely be interested in Dr. Wilson's article concerning Eros and the solar parallax which is the leader for this issue. We asked him to give some of the mathematics used in the preliminary reduction, that other practical astronomers might readily see the methods employed. This part of the work is the more important to such, because of the difference of opinion and practice, as to the most desirable method to be used in the reduction of the measures of the photographic plates containing the planet and the comparison stars.

Popular readers who are unable to follow the mathematics will readily get the purpose of the article and understand the results.

Knowledge and Illustrated Scientific News is the new title to one of our valued exchanges that has formerly been under the title of *Knowledge* only. The number for February is an excellent one and well sustains the new title.

Astronomical Photography at Yerkes Observatory.—G. W. Ritchey of Yerkes Observatory has surprised his astronomical friends by the fine photographic work he has been doing recently by the aid of the great 40-inch refractor, and the two-foot reflector. Some of the reproductions of photographs of prominent features of the Moon are themselves little less than perfect. *Mare Sereneitatis Mare Tranquilitatis* and *Mare Nubium* are examples. If the reproduction from the original negatives, by a screen of 200 probably, produces so fine and natural effect, the negatives themselves must be better.

Yerkes Observatory may well be proud of such photographic work, for we doubt if it is excelled anywhere.

Professor George E. Hale is to receive the Medal of the Royal Astronomical Society. The time set for the presentation of the medal was February 12. On account of the remarkable results obtained in solar photography Professor Hale merits this timely recognition from so worthy a source. He is now at Mount Wilson, California, carrying on some investigations pertaining to his own special line of work.

Mars Observed by Denning in 1903.—The *Astronomische Nachrichten*, No. 3926, contains an article by W. F. Denning, giving an interesting description of Mars as observed by himself during 1903. The six drawings that accompany the article give definite ideas of what this careful observer saw at the last opposition.

Phillips' Observations of Mars, 1903.—In *Monthly Notices* for November, 1903, page 39 appears an article by the Rev. T. E. R. Phillips on the Observations of Mars during last year. The article is accompanied by a fine plate showing the markings seen by him at Croydon about the time of the opposition of Mars for 1903. The instrument used was a 9¼-inch silvered-glass reflector, the mirror by With, with powers between 217 and 450. The observations were taken between the middle of February and the end of May on sixty-six occasions. During this time nearly one hundred different markings were under observation, and careful notes and drawings of the same were made and appear in this article. The author's brief summary of all this work is given below in his own words:

"To sum up the results of my observations, a careful and systematic scrutiny of the planet during the past four oppositions has revealed to me the following facts:

(1). Changes partly due to seasonal influences and the appearance of clouds and mists, partly real, unquestionably occur from time to time in the details of the surface configuration.

(2). The main results of Professor Schiaparelli's work are imperishable and beyond question. During recent years some observers have given to the so-called "canals" a hardness and an artificiality which they do not possess, with the result that discredit has been brought on the whole canal system. No doubt the time has come when a distinction must be made between what is real on Mars and what is subjective or illusory, but of the substantial accuracy and truthfulness, (as a basis on which to work) of the planet's configuration as charted by the Italian in 1877, and subsequent years, there is in my mind no doubt.

(3). Contrast, as has been so ably pointed out by M. E. M. Antoniadi, is doubtless accountable for very many of the extraordinary appearances observed on the planet. Not a few of the canals are now seen to be intensified edges of faint tones in accordance with the late Mr. Green's suggestion, while M. Antoniadi's explanation of the gemination as due to some effect of contrast appears both simple and satisfactory.

The Naval Observatory Astronomical Club.—On November 14, 1902, the members of the staff of the U. S. Naval Observatory met to consider some organization through which the current literature of astronomy and related sciences should be presented to its members by reviews or criticisms. This meeting was in response to a call by some of the members of the staff, principally, Assistant Astronomer Theo. I. King and Professor F. B. Littell, through whose efforts the organization known as "The Observatory Club" was effected.

A minimum of organization was secured in having only a "draft" presenting the objects of the Club, and for executive a "Committee of Arrangements," consisting of three members. The first committee, appointed November 14, 1902, the day of organization, consisted of Assistant Astronomer Theo. I. King, Professor F. B. Littell, and E. I. Yowell. Besides the reviews, original papers, and problems in Observatory work were presented at the weekly meetings.

On September 26, 1903, the Superintendent of the Observatory, Rear-Admiral C. M. Chester, U. S. N., recognizing the manifest advantage to all concerned, suggested a re-organization of the Club with an extension of organization and scope of work, and also with the specific inclusion of the staff of the Nautical Almanac Department in such work.

A formal constitution, adopted October 23, 1903, puts "The Naval Observatory Astronomical Club" on a basis with existing scientific associations, and gives as its objects:

"(*a*). The review of appropriate periodical literature, books, and publications of astronomical institutions.

"(*b*). The production and presentation of original papers.

"(*c*). The indexing of the literature of astronomy and related sciences."

The present officers are: Theo. I. King, President; H. B. Hedrick, Vice-President; H. R. Morgan, General Secretary; and W. D. Horigan, Index Secretary.

The advantages of such an organization in a scientific institution having the personnel and scope of work of the Naval Observatory is patent; and the con-

tinued interest of its members insures such advantages. It has been the good fortune of the Club to have eminent astronomers from other observatories take part in its weekly meetings and explain work done elsewhere.

Sun-spot Observations 1902-1903.

Month.	No. of Obs.	N. of Equator. No. Gr'ps.	Av. Lat.	S. of Equator. No. Gr'ps.	Av. Lat.	Av. No. at Each Obs.	New Gr'ps.
1902.			°		°		
Jan.	14	0	.....	1	− 10.3	0.29	1
Feb.	9	0	.....	0	.....	0.00	0
March	10	1	+ 22	0	.....	0.50	1
April	6	0	.....	0	.....	0.00	0
May	8	1	+ 24	0	.....	0.25	1
Sept.	4	1	+ 18	1	− 26	1.25	2
Oct.	21	3	+ 15.8	3	− 21.3	1.05	4
Nov.	13	2	+ 13.3	0	.....	0.31	2
Dec.	8	1	+ 20	0	.....	0.25	0
Total	93	9		5			11

Average number visible at each observation.....0.47
Average latitude of spots N. of equator.....+ 17°.8
Average latitude of spots S. of equator.....− 20°.0

Month.	No. of Obs.	N. of Equator. No. Gr'ps.	Av. Lat.	S. of Equator. No. Gr'ps.	Av. Lat.	Av. No. at Each Obs.	New Gr'ps.
1903.			°		°		
Jan.	13	0	.....	2	− 19	0.31	2
Feb.	15	2	+ 21.3	3	− 23.1	0.80	5
March	14	3	+ 21.4	2	− 20	1.00	4
April	12	4	+ 17.1	2	− 16	2.00	5
May	17	5	+ 14.7	3	− 27.8	1.23	6
June	9	2	+ 16.2	0	.....	0.44	2
Sept.	10	1	+ 9.0	0	.....	0.20	1
Oct.	17	3	+ 10.9	4	− 22.4	1.71	6
Nov.	18	4	+ 17.5	6	− 23.3	2.17	8
Dec.	13	4	+ 16.0	5	− 22.9	2.92	7
Total	138	28		27			46

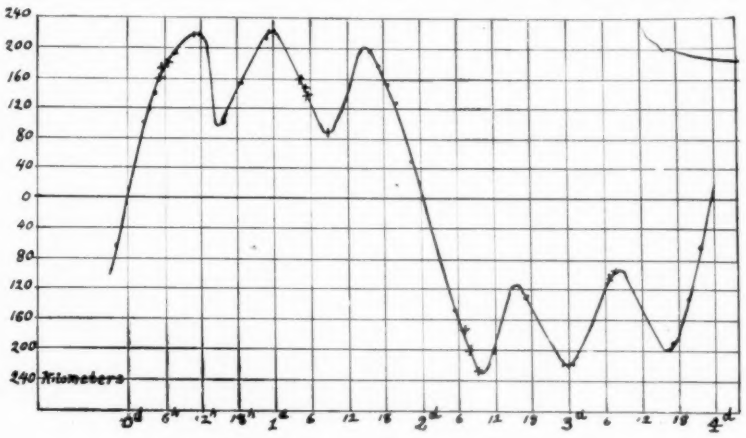
Average number visible at each observation.....1.44
Average latitude of spots N. of equator.....+ 16°.3
Average latitude of spots S. of equator.....− 22°.5

Observations were made by projecting an image of the Sun upon a screen attached to an 8-inch equatorial telescope. Latitudes were obtained with the aid of Thomson's discs.

ANNE SEWELL YOUNG.
MOUNT HOLYOKE COLLEGE.

We notice that Professor F. W. Hanawalt who has been connected for some years with the Wesleyan University at Mount Pleasant, Iowa, has recently left that place for similar work in Albion College, Albion, Michigan.

The Radial Velocity of β Aurigæ.—In *A. N.* 3916 Mr. G. A. Tikhoff of Poulkova, Russia, gives the results of a determination of the radial velocity of β Aurigæ from 41 spectograms obtained at the Observatory of Poulkova by M. Belopolsky in 1902-03. The accompanying diagram shows the curve of the radial velocity of the components of the star, and seems to indicate that the system consists of more than two bodies. The period of the principal components



RADIAL VELOCITY CURVE OF β AURIGÆ.

is found to be 3 days 23 hours and 30.4 seconds. Mr. Tikhoff states that on some of the best spectrograms the line Hγ, which is single at the time of *o* velocity, becomes quadruple at the time of maximum velocity. For example on Jan. 21, 1903 the wave lengths of the four components of the Hγ line, corrected for the movement of the Earth were:

(1)	433.866 very sharp	(3)	434.191 very sharp
(2)	433.933 quite sharp	(4)	434.253 sharp

With these wave-lengths the velocities become

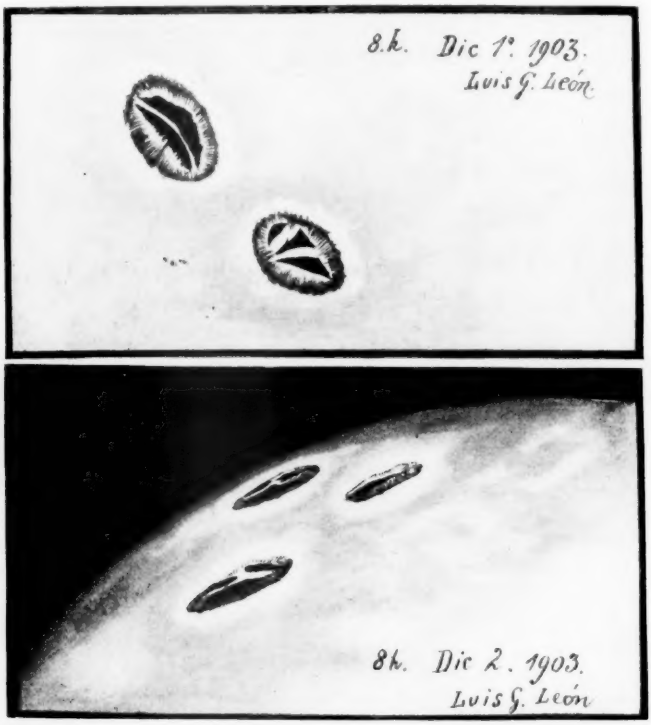
1—2	46 kilometers
3—4	43 "
1—3	224 "
2—4	221 "

The mean of the wavelengths given above is 434.061, which accords quite exactly with the value 434.059 which was determined on Jan. 24 and Feb. 3. 1903 when the line was single.

The velocity of the whole system, deduced from the Magnesium lines 448.1 and 435.2, is about — 16 kilometers per second. We thus have possibly a system of four bodies, moving as a whole toward us at the rate of about 10 miles per second, while the components form two pairs revolving about each other in 3^d $23^h.5$, each pair also revolving about its own center of gravity in something like 19 hours.

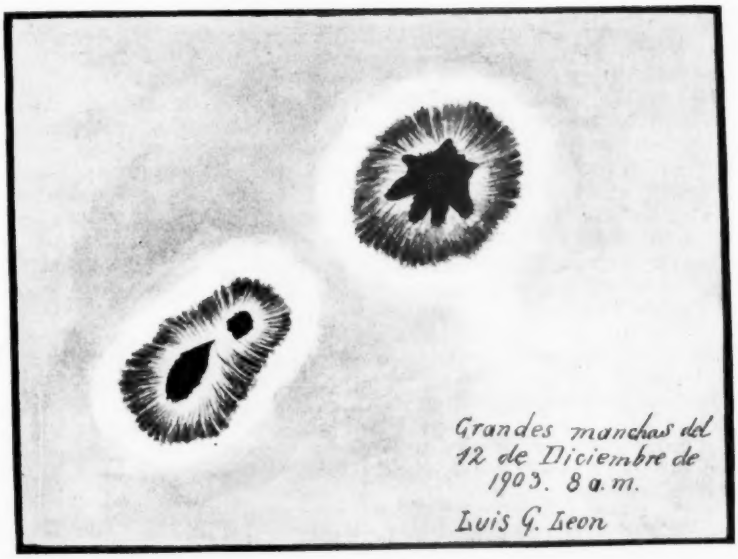
Sunspots in December, 1903.—The solar activity has continued during the month of December last. Spots and faculæ have been remarkable, especially the latter. On the first day of the month a new spot made its appearance on the eastern limb, and on the 2nd two new spots were visible in the same region. These spots were surrounded by large and brilliant faculæ. The spot which appeared on the 27th of November had the shape of a heart.

The aspect of the Sun on his eastern edge was very beautiful the 3rd of December. There was a conspicuous group of 15 spots. On the afternoon of the 6th a new spot came on the N. E. limb and still another new one was visible on the 7th. On this same day there was a group whose shape reminded one of that



of the constellation of Taurus. I believe that this group is the same famous one of the 31st of October which caused such great magnetic disturbances. On the 9th I saw a great zone of faculæ at the N. E. region of the Sun. What a tremendous activity, what a constant motion, what an immense quantity of liquid and gaseous matter combining there and sending to us waves of heat, light, electricity and magnetism! * * *

On the 10th a new spot was seen coming on the S. E. edge. On the 12th day of the month, we could admire two large spots, of peculiar shape. One gives the



Grandes manchas del
12 de Diciembre de
1903. 8 a.m.
Luis G. Leon

México. L. G. León Dic 28. 1903. 8 h.

Diciembre 29 de 1903.
8 h.
México, L. G. León

idea of a black glove and the other of an exclamation point. On the 15th was a new spot at the N. E. This spot presented on the 18th the form of an insect with only three legs, and the 19th separated in two parts, as my drawing shows. On the 22nd the eastern part of the spot divided in two.

Something very curious happened on the Sun the 20th. A group appeared, but not on the eastern edge as is usual; but near the western edge. It was a sudden eruption, and I dare to say that this perturbation was, very likely, due to the attraction of Mars and Saturn which were in conjunction exactly on the same day.

On the 24th began on the Sun a period of rest. On the 26th not a single spot was visible; but a day afterwards 4 spots came at the N. E. with splendid faculæ. New spots on the 28th and the 29th on the eastern limb were seen.

Fifteen new spots made their appearance on the Sun during the month of December, 1903, and brilliant faculæ accompanied them.

I take pleasure in suggesting to the observers of the Sun that they make their drawings on gray paper with lead pencil, representing the faculæ with white pencil.

PROF. LUIS G. LEON.

MEXICO CITY, January 1st, 1904.

Auroral Arch, Aug. 21, 1903.—Having read with interest the various accounts in POPULAR ASTRONOMY of the Aurora Boreallis seen over such a large area on the night of August 21, I should like to say that I saw the same phenomenon on the same evening at Duxbury, Mass., a town about 37 miles south of Boston. The description given by the Rev. Mr. Campbell agrees almost exactly with what I saw. The arch I saw was not quite so near the zenith as that seen by Mr. Campbell. In this connection it is interesting to note that the arch seen by Mr. Blatchley at Wayne, Pa., was very far down on the horizon. The highest part of the base of the columns was just below Theta Ursa Majoris, he says. Now I believe that the various arches seen by all of us were really one and the same, or parts of the same, arch. I think that this arch was a ring or arc of a circle extending across the country east and west for many miles, high up in the air, and about overhead on the latitude of the Adirondacks, which very nearly corresponds with the latitude of the parts of Montana, Maine, and New Hampshire where it was seen. The fact that the arch ran east and west would account for the fact that there was no easterly or westerly deviation at these points. But at both Duxbury, Mass., and Wayne, Pa., where it was seen, there should have been, if my supposition is true, a northerly deviation, due, of course, to parallax. And in both the cases the deviation was noticed, and furthermore, it was more pronounced at Wayne, which is farther south than Duxbury. All this would seem to point to the one arch theory, which I believe is the correct one.

H. M. T.

Jan. 9, 1904.

BOOK NOTICE.

Elementary Plane Geometry by McMahon.—The Cornell series of mathematics now includes Analytic Geometry by Tanner and Allen, Differential Calculus by McMahon and Snyder, Integral Calculus by Murray, a single volume

of the Differential and Integral Calculus by Snyder and Hutchinson, Elementary Geometry by Tanner, and the new and latest book on Plane Geometry by James McMahon which has just been received. The series as a whole is strong and thoroughly modern in matter and method. In the class-room the earlier books in Calculus and Analytic Geometry have stood the test well, and won for their authors high commendation for practical worth, rigorous method and well chosen matter. The book before us has points of special interest, in the treatment of Elementary Plane Geometry. They are briefly:

1. Soundness of structural development.
2. Distinction between Euclidean space, and non-Euclidean space.
3. The meaning and true place of postulates.
4. The grouping of theorems and problems so as to unfold logically space relations.
5. The treatment of size relations as purely geometrical.
6. Euclidean doctrine of ratio and proportion is put in modern form.
7. The measurement of a circle is based on the definition of the length of a curved line in terms of a straight measuring unit.

These are some of the more prominent features of this new Geometry that will quickly catch the eye of teachers of this branch. Those instructors who *think* and prepare themselves *very thoroughly* will also be interested in the following paragraph taken from page 8:

"The postulates as defining Euclidean space. A space that fulfills the conditions embodied in the postulates and primary definitions is called a *Euclidean space* after the name of Euclid, who wrote the first systematic treatise on geometry. We can never be absolutely certain, at least with our present mode of perception, that our space is of the ideal Euclidean character, but there is no doubt that, for all human needs, it may be regarded as accurately Euclidean.

A perfect system of postulates should embody the primary notions that are necessary and sufficient to distinguish Euclidean space from other kinds of space, and to furnish a starting point from which all its properties could be derived by a chain of reasoning without further resort to experience. Euclid and the ancient geometers did not give close attention to the necessity and sufficiency of their system of conventions. They silently took for granted certain things that do not follow from previously accepted principles; and some of their fundamental conventions are not independent of each other. Modern geometers are not yet entirely agreed on a complete system of mutually independent postulates for Euclidean space, and the full discussion of this question goes beyond the limits set for elementary geometry.

Several different systems of non-Euclidean geometry have been studied, each of which dispenses with one or more of the characteristic properties of Euclidean space. The most celebrated of these systems dispenses with the 'postulate of parallels,' which will be introduced in the proper place. It should be observed that if only the 'postulate of dimensions' is dispensed with, the space is still Euclidean in character, for a Euclidean three-dimensional space may be regarded as existing in a Euclidean space of four or more dimensions, just as a two-dimensional space exists in a three-dimensional one. A Euclidean space of more than three dimensions is called a Euclidean hyper-space."

General attention is called to this new book as a basis for the study of the higher mathematics.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

Proofs will generally be sent to authors living in the United States, if copy is furnished before the tenth of the month preceding that of publication. We greatly prefer that authors should read their own proofs, and we will faithfully see that all corrections are made in the final proofs.

Renewals.—Notices of expiration of subscription will hereafter be sent with the last number of this publication for which payment has been made. It is especially requested that subscribers will send renewal, or order for renewal promptly as this publication will not be continued beyond the time for which it has been ordered.

Astronomical News.—It is very much desired on the part of the management, that brief news paragraphs of astronomical work in all the leading observatories of the United States be furnished to this publication, as regularly and as often as possible.

The work of amateur astronomers, and the mention of "personals" concerning prominent astronomers will be welcome at any time.

The building and equipping of new observatories, the manufacture, sale or purchase of new astronomical instruments, with special reference to improvements and new designs, and the results of new methods of work in popular language, will be deemed very important matter and will receive prompt attention. Appropriate blanks have been prepared and will be sent out generally to secure this important information. It is greatly desired that all persons interested bear us in mind and promptly respond to these requests.

Messrs. Wm. Wesley & Son, 28 Essex Street, Strand, London, England, are our sole European agents.

Reprints of articles for authors, when desired, will be furnished in titled paper covers at small cost. Persons wanting reprints should order them when the manuscript is sent to the publisher. They cannot be furnished later without incurring much greater expense.

Subscription Price to Popular Astronomy in the United States, Canada and Mexico is $2.50 per volume of 10 consecutive numbers. Price per volume of 10 numbers to foreign subscribers $3.00.

All correspondence and all remittances should be sent to

WM. W. PAYNE,
Northfield, Minn., U. S. A.